VOL. XXXVII. — No. 9. SEPTEMBER 1960.

Monthly Bulletin of the International Railway Congress Association

(English Edition)

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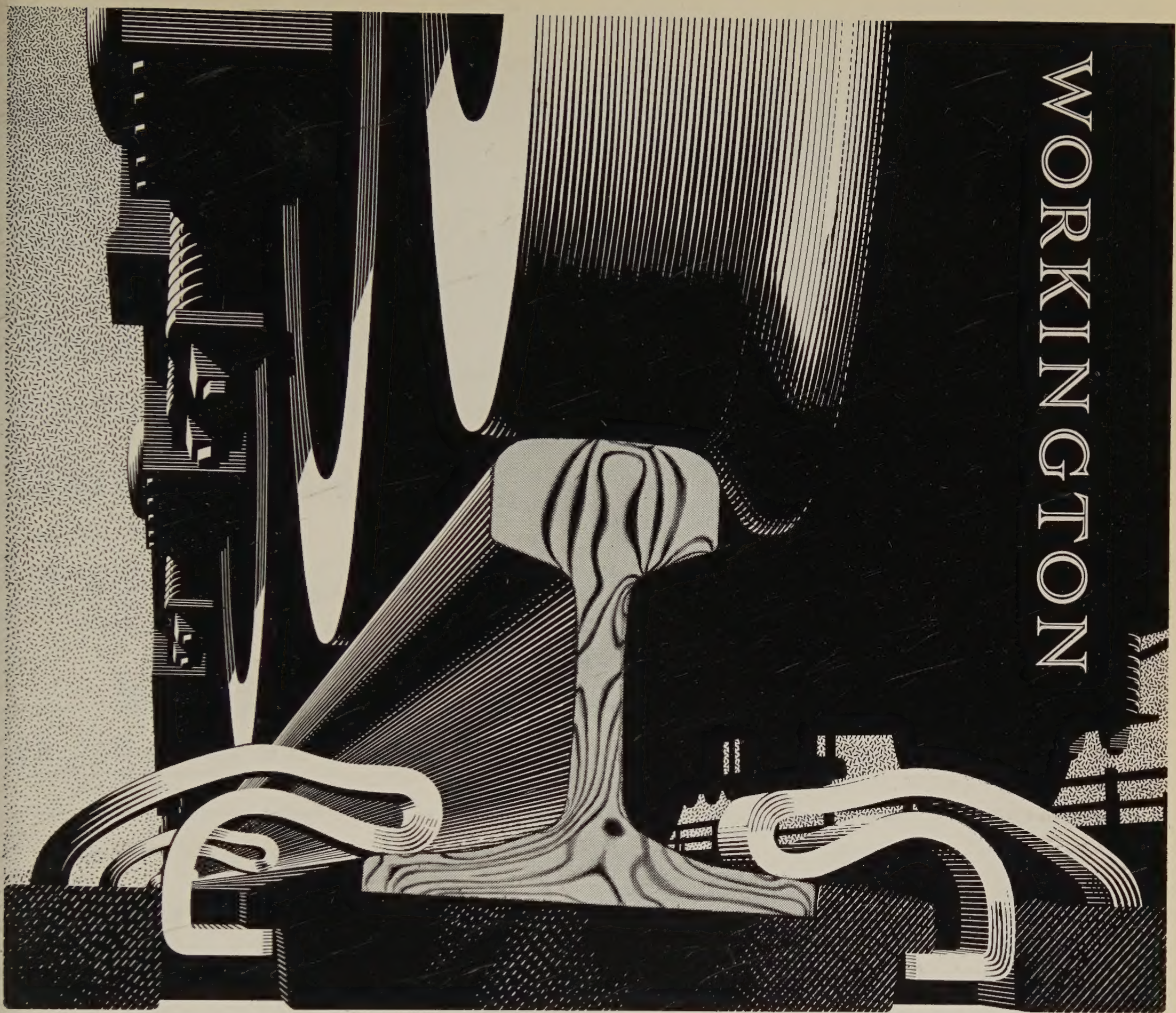
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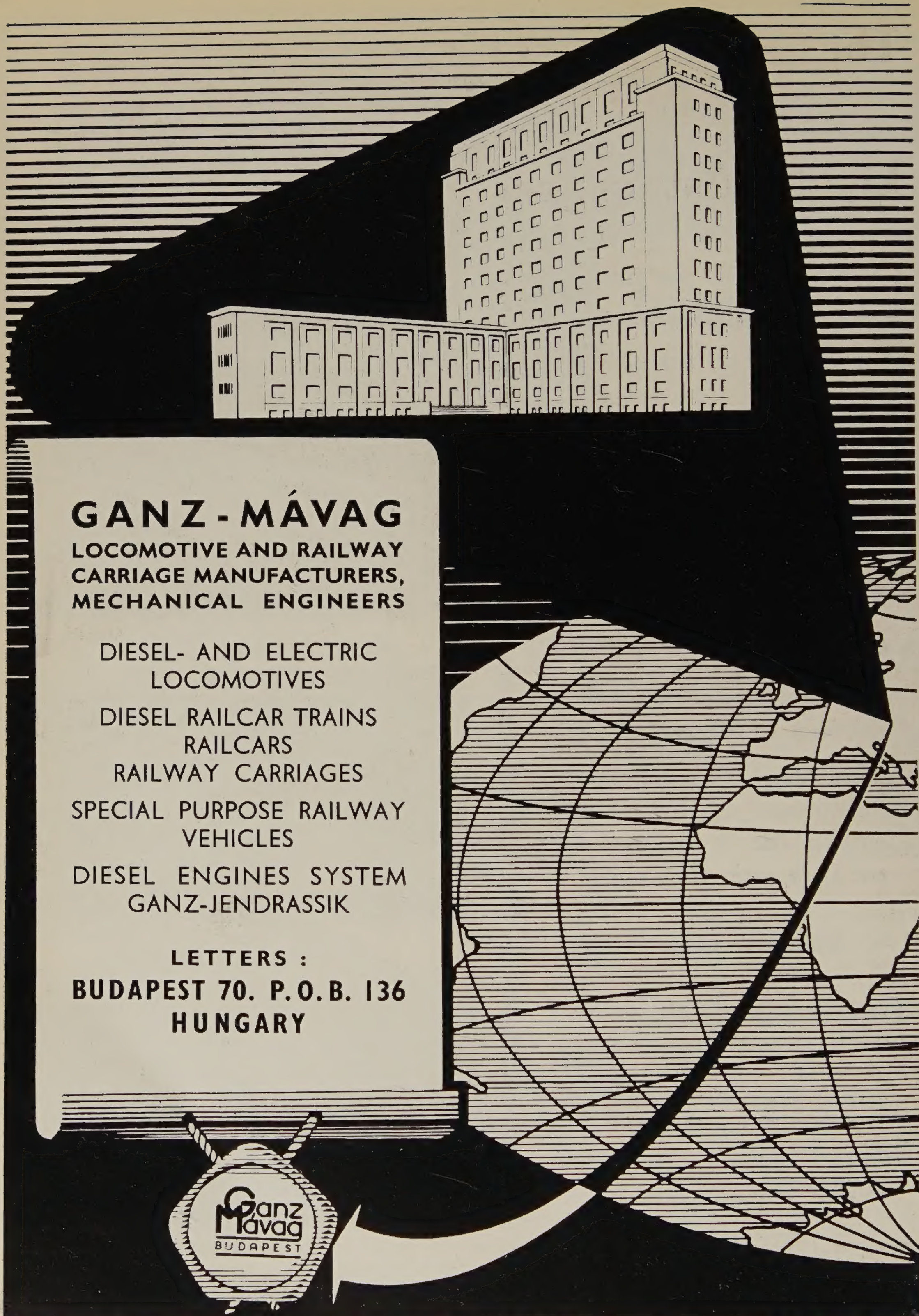
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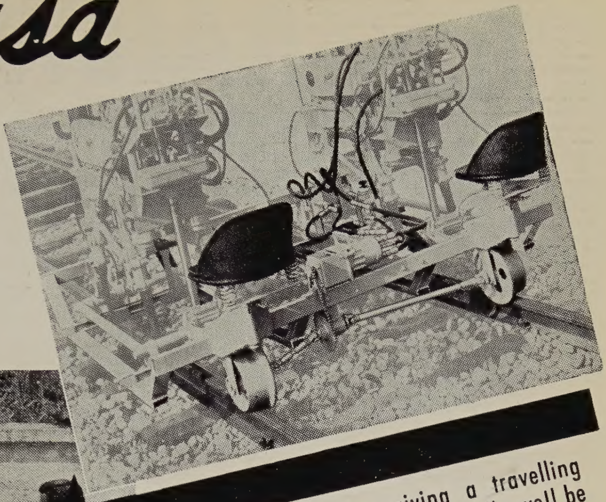

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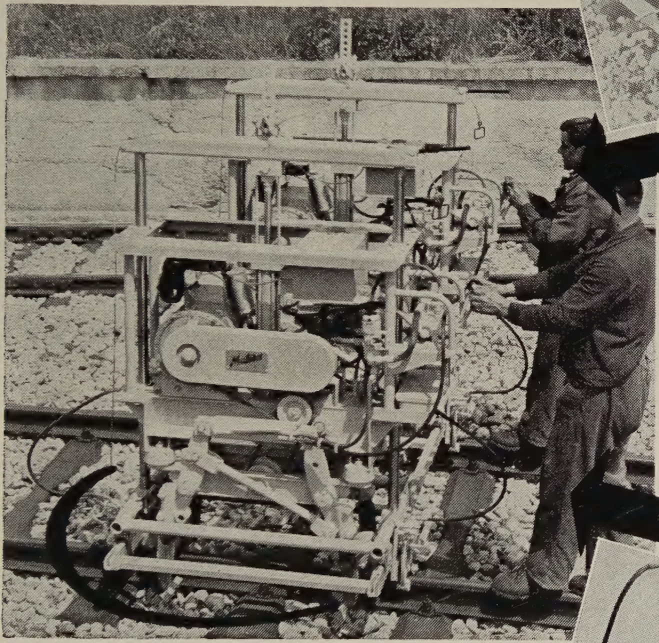

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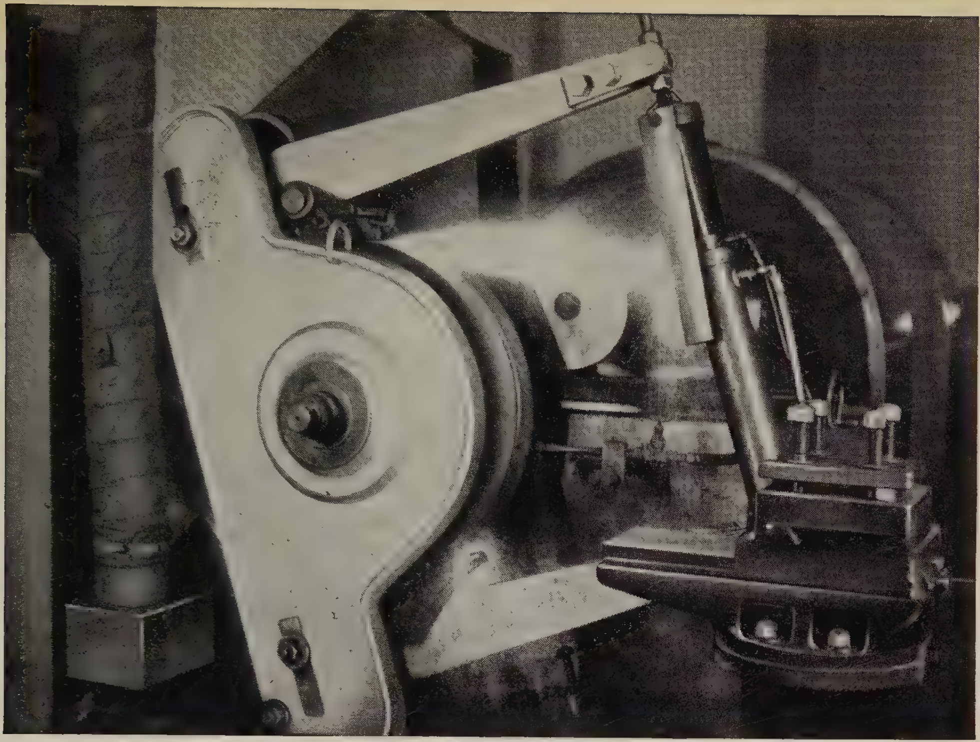

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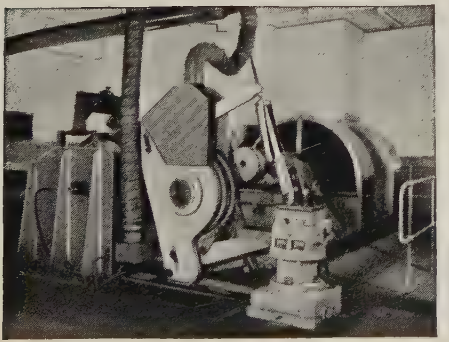

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Vol. XXXVII. — No. 9. September 1960.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[656 .21]

The capacity of the installations of sidings in stations,

by Dim. S. Živković,

Departmental Head & Councillor at the General Management of the Jugoslavian State Railways.

In the present article, we propose to make certain theoretical researches into the calculation of the capacity needed for installations of sidings in stations. Today, when the number of trains on the different lines increases from day to day, it is of the greatest interest to determine the limit of use of the existing tracks. In the same way, in analysing the utilisation of the existing installations, i.e. in comparing the work done and the given organisation or given volume with the present position regarding the output of the tracks, certain calculations are necessary in order to determine the margin available or any bottlenecks.

In the first case, for a given amount of work, the number of sidings of a certain length required, or the necessary siding length will be calculated. In the second case, a comparison is made between the given amount of work and organisation, and the number of sidings or length of sidings already given.

In carrying out the calculations in both cases, the following methods are used :

In the first place, it is necessary to determine the volume of work, i.e. the task on which the calculation of the necessary capacity of the station sidings is based. The volume of work, in other words the task, must be determined as a normal daily maximum, taking into account daily variations. This is what is meant by " peak work ", i.e. the most unfavourable normal case.

In the second place, it is necessary to determine the factors (standards) to be included in the calculation, such as for example, the time the wagons remain in the shunting yards, the type and period of the timetable for the line in question.

Finally, it is necessary to establish the coefficient of user of the sidings, irregularities, etc.

In so far as it is a question of predetermining the capacity of the track installations, the standards must be so established as to take into account future improvements in the working, both from the point of view of the organisation and of the mechanisation of the latter. If it is a question of analysing the work, the standards must be based on the most favourable value obtained, or else be calculated by taking a given organisation of the work and the existing state of mechanisation as the basis.

The necessary work factors, standards and coefficients being determined regularly and exactly, it becomes possible to proceed to making the calculations. The difficulties reside in determining and establishing accurately certain factors in the calculation rather than in arriving at the mathematical expressions properly speaking. In this connection, the determination of the value of isolated elements is of importance as well as the need for these to be brought out in the processus of the work itself, just as it is no less important that the mathematical expression in its turn, no matter how simple, corresponds to reality.

The essential objective of the present article is to endeavour to establish theoretical relations offering sufficient reliability as regards these points. Thus, for example, the number of tracks in the intermediate stations does not depend upon the number of pairs of trains, but on the type of the working diagram. The number of tracks can only depend upon the number of trains and the time they remain on the sidings in those yards where the trains are made up or divided up, but not in the intermediate stations which they merely run through.

In addition, when it is a question of breaking the trains up into a certain number of cuts, the number of tracks (G) is a function of the number of these cuts. The length of these tracks must be determined according to the maximum length of the trains or the size of the cuts or the flow of goods.

In the case of work to be carried out on the wagons, or the handling of goods, it is necessary to calculate the length of sidings required according to the amount of work and the organisation in question.

We will study in turn, in these considerations, the calculating of the capacity of the sidings in the following stations :

a) Intermediate stations;
b) Goods yards;
c) Marshalling yards (service yards); and
d) Passenger stations.

A. INTERMEDIATE STATIONS

In order that the intermediate station shall be able to fulfil its responsibilities as regards the trains passing through it, in other words the crossing and running round of the trains as well as loading or unloading goods, it must have at its disposal :

1) installations of sidings over which the trains pass, as well as
2) installations for loading and unloading goods.

1. Installations of sidings over which the trains pass.

The capacity of the sidings installations for trains passing through the intermediate stations is shown by the work processus, i.e. according to the type of graph.

The graph for a single track with the trains spaced out according to the distance is correctly drawn when, at any given moment, on any part section the number of trains equals the number of intervals between stations. For example, on the graph for the part section *a* — *e* (fig. 1) where there are four intervals between stations, there must never be more than four trains on the section. The despatching of any additional train would therefore be wrong. The fifth train could only be sent forward from the departure station on condition that one of the trains

already in the section were stopped in one of the intermediate stations. The stopped train could only resume its journey if another train were stopped, and so on. This is why in practice a graph meeting the above conditions is the only one that can be adopted. If this diagram is correctly determined, the number of tracks required for the running of the trains is also determined from this graph.

In the case of single line working, when the parallel graph is used with even numbers of trains (fig. 1), it is necessary for the intermediate station to have two tracks (one of which is the main line) used exclusively for the passing (crossing over) of the trains. The useful length of these two tracks (their mutual ratio) is similar. The useful length must meet the length of the longest train, including the maximum number of locomotives that will be used on the train.

The expression for calculating the length of the maximum train (= useful length of the track) is as follows :

$$L_{Nu} = m_{max} \cdot l_w + M \cdot l_L \quad (1)$$

In this expression :

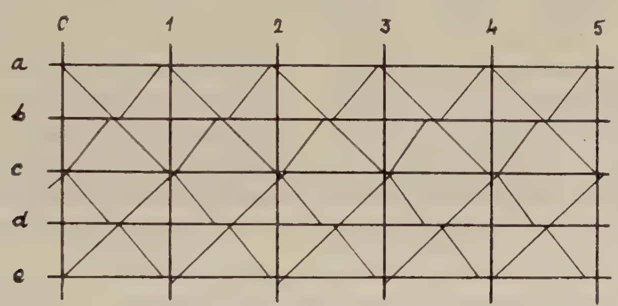
L_{Nu} = maximum length of the trains, or useful length of the track, in m;

m_{max} = maximum number of wagons in the train;

M = maximum number of locomotives on the train, and

l_w, l_L = average lengths respectively of a wagon and of a locomotive, in m.

In the case of single track working, with a non parallel graph (commercial) (fig. 2) the intermediate station must have three tracks used exclusively for the passing (crossing and passing) of the trains in order to utilise correctly the traffic capacity of the line (on the graph of fig. 2, in station b, time spent in station about 4 hours). These three tracks must all have the same useful length as previously (equal to the maximum length of the train, including the length of the locomotives hauling it). Some people, however, are of the opinion that the third track might have a slightly reduced useful length, in other words it can be shorter by an amount which is dictated by the reciprocal connections between the tracks. This opinion has been applied in practice. The admissible number of axles on the line is determined by its relation with the main passing line (the longest passing line). When crossing, the longest trains can cross without difficulty. A third



Fig, 1.

track, shorter, could not be used in this case. When two trains of the maximum length cross, such an intermediate station fulfils the same role as a two-track intermediate station.

When the capacity as regards passing is preferable to equip with three tracks all the intermediate stations close to the spacing which limits the capacity or close to differing spacings from the point of view of the journey times, of a pair of trains in the limiting spacing.

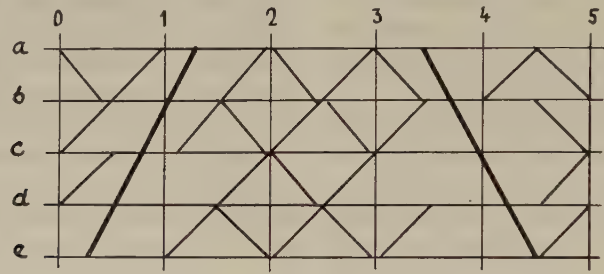


Fig. 2.

is not fully utilised, and more particularly when the intermediate station is not situated close to the spacing which limits the capacity of the line, the intermediate station may also meet requirements with

In the case of single line traffic, with a non-parallel graph (commercial) when the traffic is organised according to the block or automatic block intervals (fig. 3), the intermediate station must have a num-

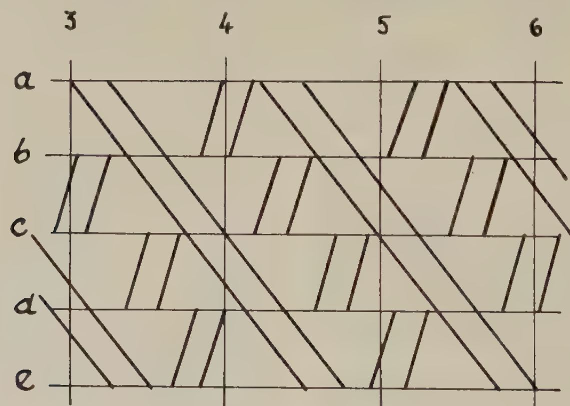


Fig. 3.

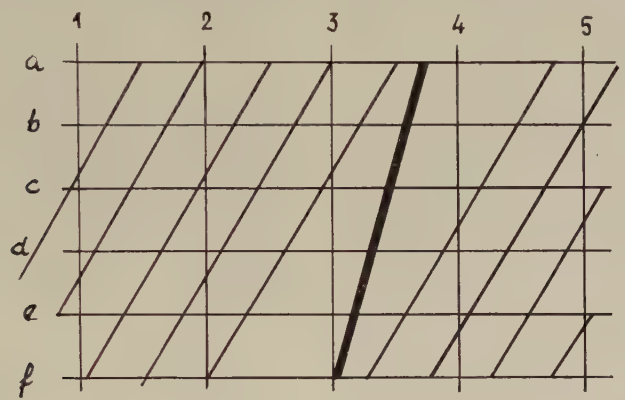
two tracks. With a growing utilisation of the capacity of the line as regards passing, the tracks also have to be completed (the third tracks) in the intermediate stations. It goes without saying that it

ber of tracks double the number of trains in the group. As groups of pairs of trains are commonly used, it follows that the intermediate station must have four tracks for the passing (crossing and over-taking)

of trains. In this case again, some people think that three of these tracks, one of them being the main line, must have a sufficient useful length to take the longest train (L_{Nu}). It is desirable that the fourth track be equally long, but in view of the mutual linking up of these tracks, it may have a shorter useful length.

Here again it is allowable for the intermediate station only to have three tracks so long as the capacity as regards trains passing is not fully utilised. The capacity is not sufficiently utilised when the groups of trains in the opposite direction are not complete. The useful length remains the same, for these three tracks also; it must correspond at least to the length of the maximum train.

In the case of double track working when the operating makes no provision for trains passing each other in the intermediate stations, the intermediate station must have a track in each direction for trains to pass each other.



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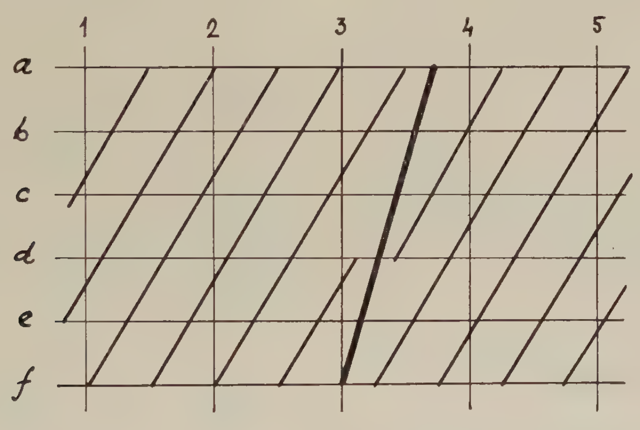

Fig. 5.

In the case of double track working where the operating requires trains to pass each other at the intermediate stations (fig. 5), the station must have two tracks in each direction for the trains to pass each other. The useful length of these four tracks must correspond to the maximum train length (L_{Nu}).

If, in this latter case, the intermediate station is equipped with signalling and safety installations which guarantee that the points and signals are interlocked, the intermediate station can have a total of three tracks for the two directions. In this case, a single passing track is used for both directions of running. The useful length of this track must correspond to the maximum train length (L_{Nu}).

This method is justified because of the fact that with the increase in the speeds of the goods trains, it is rare for trains to overtake each other in the intermediate stations with double lines during the 24 hours.

Finally, it should be noted that we have only considered typical cases of the graphs. Special cases, such as graphs for unequal numbers of trains, or graphs at advertised intervals when the groups consist of three or four trains, must be studied specially, according to the principles laid down above.

2. Installations of sidings for loading and unloading wagons.

The handling, loading and unloading of wagons in the intermediate stations are generally of slight importance, so that one so-called handling siding is not only sufficient, but often superfluous owing to its excessive length, if it is connected directly with the train passing sidings. If it is necessary to carry out much handling on the wagons, a check should be made to see that the useful length of the handling siding (the length required for the operations to be carried out) corresponds to working conditions.

In order to determine the useful length of the siding for handling the freight, it is necessary to establish the maximum daily figures for the following elements :

a) number of wagons to be loaded : (U_{Be});

b) number of wagons to be unloaded : (U_{Ent});

c) number of wagons arriving at the station empty : (U_{le}), if there are not sufficient wagons for loading from the unloaded empties;

d) average time spent by the wagons in the station for handling the freight (t_G) in hours. Here the month with the greatest volume of work will be taken as basis;

e) coefficient of user of the track for which work on the wagons is assured without mutual inconvenience ($\gamma < 1$). Provisionally, we will give this coefficient a value of 0.7 to 0.9.

The useful length of the siding for handling the freight on the wagons (L_G) is therefore in metres :

$$L_G = \frac{(U_{Be} + U_{Ent}) \cdot t_G \cdot l_w}{24} \qquad (2)$$

whence :

$$L_G = \frac{(U_{Ent} + U_{le}) \cdot t_w \cdot l_w}{24} \qquad (3)$$

t_w being the average time spent by a wagon in the station in hours, no matter what handling of goods has to be carried out on the wagons.

In this case we get :

$$t_w = \frac{(U_{Be} + U_{Ent})}{(U_{Ent} + U_{le})} \cdot t_G = K_{Dop} \cdot t_G \quad (4)$$

in which K_{Dop} designates the coefficient of double handling.

Example: To determine the useful length of siding for handling freight in the wagons, if $U_{Be} = 5$ wagons, $U_{Ent} = 8$ wagons, $U_{Le} = 2$ wagons and $t_G = 20$ hours. For the normal siding l_W can be taken as equal to 10 m and $\gamma = 0.8$.

$$L_G = \frac{(5 + 8) \cdot 20 \cdot 10}{24 \cdot 0.8} = \text{approx. } 135\ \text{m},$$

or, if :

$$t_W = \frac{5 + 8}{8 + 2} \cdot 20 = 26\ \text{h},$$

then :

$$L_G = \frac{(8 + 2) \cdot 26 \cdot 10}{24 \cdot 0.8} = \text{approx. } 135\ \text{m}.$$

B. GOODS YARDS

By goods yards, we mean in this case also an intermediate station on the line, where considerable handling has to be done, so that in addition to the tracks needed for the trains to pass each other, there must also be sidings for these handling operations, in other words sidings to make up or divide up the trains with arrivals or departures from the local station.

As a result in such stations, the three following categories of sidings are required :

1) track installations to allow trains to pass through;
2) track installations for making up and shunting the local traffic;
3) sidings for handling operations to the wagons.

1. Track installations to allow trains to pass through.

As the goods yard is like an intermediate station from the point of view of the line, what we said above regarding intermediate stations also applies in this case. According to the train passing capacity and the type of graph, there must be three or four tracks for trains to pass through, and their useful length must correspond to the maximum train length (L_{Nu}).

2. Track installations for making up and shunting local traffic trains.

Here again, it is necessary to determine the work factors mentioned above as maximum daily figures (U_{Be}, U_{Ent}, U_{le}) as well as the standards (t_G, t_W, l_W). As coefficient of user of the track installations for making up and shunting the trains, we will provisionally take the value $\gamma = 0.5$.

The standard figure for the average time spent by the wagons in the station (t_W) must be divided into two parts : the time spent on the track installations for making up and shunting the trains (t_Z) and the time spent on the sidings for handling the freight (t_{Arb}).

The loaded wagons to be unloaded (U_{Ent}) as well as empty wagons to be loaded (U_{le}) come into the yard directly onto the sidings concerned. The wagons remain on these sidings while the train is being shunted until they are put onto the sidings where the freight is handled, in

other words for t_{Z1} hours. They remain on the sidings where freight is handled from the time they are made available for these operations until the operations are completed (unloaded followed by loading again, or loading only) in other words for t_{Arb} hours. When handling operations are completed, the wagons are transferred to the marshalling sidings, where they remain until the train is made up, in other words until the train leaves, for t_{Z2} hours. In each particular case, the time t_Z has to be determined by a thorough analysis. If the time spent by the wagons on the sidings for making up and shunting the trains $t_Z = t_{Z1} + t_{Z2}$ is known, the time they spend on the sidings for handling the freight (t_{Arb}) becomes :

$$t_{Arb} = t_w - t_Z \text{ hours.} \qquad (5)$$

The necessary length of the track installations for the making up and shunting of the local traffic trains (L_B) is determined by the following expression :

$$L_B = \frac{(U_{Ent} + U_{le}) \cdot t_Z \cdot l_W}{24\,\gamma} \qquad (6)$$

The approximate number of sidings (G_B) is determined by dividing the length L_B by the maximum length of the local train L_{Nu}, in other words :

$$G_B = \frac{L_B}{L_{Nu}} \qquad (7)$$

and rounding off the result to the next highest number.

Of the total number of sidings, two must have as their useful length L_{Nu} metres (maximum length of the local traffic trains). The other sidings can be shorter, depending upon their connections with each other, but their total length must amount to L_B metres. If in the calculation, we get $G_B < 2$, two sidings will be required, but each of these must have a useful length of at least L_{Nu} metres.

These goods yards do not usually have any special tasks to fulfil as regards sorting the local traffic, so that only two sidings are needed to make up the trains. Should the contrary be true, if they have some special task (sorting of wagons in stations beyond the adjoining distribution stations) the question of groups of tracks for shunting and forwarding must also be gone into for these yards. As regards the classification of arrivals by unloading stations, it may also be necessary to provide a group of shunting sidings, if such classification is not possible on the unloading sidings themselves. In general, it will be possible to do it in this way if work on these sidings is carried out without interruption.

Finally, if it is question of a number of wagons which will only require two sidings on the group of sidings in question, the timetable will be prepared in such a way that the train bringing in the wagons to the goods yard only arrives when the wagons to be sent forward, even if not removed from the unloading siding and the train made up, are at least loaded and ready to be taken away to make up the train. This depends entirely upon the work of the clients and the shunting locomotive put at their disposal.

In such yards, there may also be a question of making a so-called locomotive siding for taking the locomotive coming from the train or going to take the train away. But such a siding is only necessary

if the group of sidings is not directly linked up with the train passing tracks, in other words if they are some distance apart.

3. Track installations of sidings for handling the freight in the wagons.

The total length of the sidings installations for handling the freight in the wagons can easily be determined if the time t_{Arb} is known, by using the expression (3) in which t_W is replaced by t_{Arb}.

We then have :

$$L_G = \frac{(U_{Ent} + U_{le}) \cdot t_{Arb} \cdot l_w}{24 \cdot \gamma} \qquad (8)$$

The time t_{Arb} in hours is standardised per wagon. To determine the length of the different sidings, it is much more convenient to work with the number of handling operations to the freight and the time the wagons remain on the sidings during handling (t_{uG}). This is calculated as follows :

$$t_{uG} = \frac{(U_{Ent} + U_{le})}{(U_{Be} + U_{Ent})} \cdot t_{Arb} = \frac{t_{Arb}}{K_{Dop}} \qquad (9)$$

To determine the length of certain sidings L_{G1} (handling sidings), L_{G2} (sidings for unloading coal), it is necessary to take not the number of wagons ($U_{Ent} + U_{le}$) but the number, already known, of handling operations to goods on the siding in question ($U_{Be} + U_{Ent}$) and the time t_{uG}. Consequently :

$$L_{Gx} = \frac{(U_{Be} + U_{Ent}) \cdot t_{uG} \cdot l_w}{24 \cdot \gamma} \qquad (10)$$

on condition that :

$$L_{G1} + L_{G2} + \ldots + L_{Gn} = \text{approx. } L_G \qquad (11)$$

Example : To determine the track installations for a goods yard when the intermediate station is on a single line, the train spacing from station to station, the commercial graph, the intensive user of the train passing capacity, the maximum length of the trains $L_{Nu} = 550$ m, the length of the local traffic trains $L'_{Nu} = 450$ m, $U_{Be} = 100$ wagons, $U_{Ent} = 60$ wagons, $U_{le} = 70$ wagons and $t_G = 22$ hours.

Solution : ad (1); three sidings; useful length at least $L_{Nu} = 550$ m;

ad (2) :

$$t_W = K_{Dop} \cdot t_G = \frac{(U_{Be} + U_{Ent})}{(U_{Ent} + U_{le})} \cdot t_G$$

$$t_W = \frac{(100 + 60)}{(60 + 70)} \cdot 22 = 1.23 \cdot 22$$

$$= \text{approx. } 27 \text{ h.}$$

We will take it that $t_Z = 6$ hours and $l_W = 10$ m.

$$L_B = \frac{(U_{Ent} + U_{le}) \cdot t_Z \cdot l_W}{24\,\gamma}$$

$$= \frac{(60 + 70) \cdot 6 \cdot 10}{24 \cdot 0.5} = 650 \text{ m}$$

$$G_B = \frac{L_B}{L'_{Nu}} = \frac{650}{450} = \text{approx. } 1.4.$$

As in this case we get $G_B < 2$, we can take $G_B = 2$ both having a useful length of 450 m.

ad (3) : Hypothesis : $\gamma = 0.7$.

$t_{Arb} = t_G - t_Z = 27 - 6 = 21$ h,

$$t_{uG} = \frac{t_{Arb}}{K_{Dop}} = \frac{21}{1.23} = \text{approx. } 17.1 \text{ h,}$$

$$L_G = \frac{(U_{Ent} + U_{le}) \cdot t_{Arb} \cdot l_W}{24\,\gamma},$$

$$L_G = \frac{(60 + 70) \cdot 21 \cdot 10}{24 \cdot 0.7} = \text{approx. } 1\,625 \text{ m.}$$

The total length of sidings required will therefore amount in round figures to 1 625 m.

Let us suppose that the total handling operations to be carried out are as follows :

a) handling : 10 loadings and 10 unloadings;

b) fuel, building materials, timber for building, etc. : 20 loadings and 40 unloadings, and finally

c) miscellaneous : 70 loadings and 10 unloadings.

With such a distribution of the work, the lengths of the different sidings are as follows :

ad *a*) for handling operations :

$$L_{G1} = \frac{(10 + 10)\ 17.1 \cdot 10}{24 \cdot 0.7} = \text{approx. } 203 \text{ m},$$

ad *b*) for fuel, building materials, etc. :

$$L_{G2} = \frac{(20 + 40)\ 17.1 \cdot 10}{24 \cdot 0.7} = \text{approx. } 610 \text{ m},$$

and :

ad *c*) for miscellaneous operations :

$$L_{G3} = \frac{(70 + 10) \cdot 17.1 \cdot 10}{24 \cdot 0.7} = \text{approx. } 814 \text{ m}.$$

In the extreme case, the distribution might be as follows :

ad *a*) handling siding about 200 m useful length;

ad *b*) 2 sidings, each about 300 m useful length for fuel and building materials;

ad *c*) 3 sidings about 270 m useful length for other requirements.

(The time t_{uG} may vary according to the unloading points.)

C. SHUNTING YARDS (service yards).

The arrangement of shunting yards may vary as regards the number and location of the groups of sidings. Unilateral shunting yards have either only two ladder tracks : the arrivals group and a common group for shunting and leaving, or three ladder tracks : entry, shunting and leaving. Bilateral yards may have four or six groups of sidings, etc.

To be able to carry out its task, each shunting yard must have a sufficient length of sidings for the operations to be carried out on the wagons.

A shunting yard must have the following installations of sidings :

1) train reception;

2) shunting, with or without outwards sidings;

3) train despatching.

In addition to these sidings, a shunting yard may also have the following installations :

a) lines for trains in transit;

b) sidings for shunting the local traffic (connections and stations served directly).

In the case of shunting yards, the work factors as well as the standards are somewhat greater. In a yard of this type, certain wagons may have to be shunted two or three times in order to be grouped (units to be unloaded, possibly units to be brought back, etc.). For example, of the total number of wagons coming in during the 24 hours (N), the wagons to be un-

loaded in the yard in question (U_{Ent}) or empty wagons for loading (U_{le}) are shunted three times and grouped twice.

They are shunted the first time when the train is shunted on arrival. They are then accumulated until the siding in question has a sufficient number of wagons for unloading or empty wagons, and this lot is then shunted so that the wagons are in position for unloading. Shunting this lot per unloading point necessitates a second sorting of the wagons. The third sorting takes place when the unloaded or loaded wagons, or empty wagons that have been unloaded, are removed from the sidings and placed on a siding corresponding with a group to be formed in the yard. The wagons accumulate on this siding for the second time, until there is a sufficient number, after which they are made up into a train so that they may even be shunted a fourth time (units collected together, possibly to make up the train as required technically). As a result in the shunting yards it is necessary to determine the following values, once again as the daily maximum :

a) number of wagons arriving each day at the shunting yard or consigned from it in the 24 hours (N);

b) number of these wagons arriving at the shunting yard to be unloaded (U_{Ent}) and number of these empty wagons coming in to be loaded (U_{le});

c) of the total number of wagons passing through the yard, the number of " back shunted units ", i.e. the number which change their direction of running at the yard ($U_{Rück}$), taking into account in the case of these wagons that it may be necessary to shunt or marshall them twice, and finally

d) out of the total number of wagons, the number which merely run through the yard without any handling of the load (U_{tr}).

In addition to the values mentioned above (t_G, t_W, l_W, t_Z, t_{Arb}, t_{uG}, γ), the following also have to be determined :

a) average length of time a wagon stands on the siding whilst waiting till a sufficient number of wagons m has been accumulated to make up a train (t_{Ans}) :

$$t_{Ans} = \frac{12\, m\,(k - 1.6)}{N} \text{ hours}^{(1)} \qquad (12)$$

In this formula, the letters have the following meaning :

m = average composition of the train or lot of wagons sent on separately;

k = number of directions or number of lots formed for each station concerned, according to the distribution of the marshalling work on the system;

N = total number of wagons accumulated.

b) the average time, expressed in hours, the train stands on the reception sidings until it is shunted (t_{Zer});

c) average time taken for the technical formation of the train (or lot) of m wagons from the time they have been accumulated until they are sent off by train (t_{Zus});

(1) For further details, see *Congress Bulletin*, February, 1957 : « Determining the marshalling times of wagons in marshalling yards ».

d) length of the diagram period (T) for each single line running into or out of the shunting yard, in order to obtain the maximum passing capacity, according to the expression :

$$T = \frac{1\,440}{n_{G_{ford}} + E\, n_{P_{ford}}} \text{ minutes} \quad (13)$$

in which :

$n_{G_{ford}}$ = maximum number of pairs of goods trains needed;

$n_{P_{ford}}$ = maximum number of pairs of passenger trains needed;

E = coefficient of deduction.

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e) time between successive goods trains (I_t) for each double line running into or out of the shunting yard, in order to obtain the maximum passage capacity, according to the expression :

$$I_t = \frac{1\,440}{n_{G_{ford}} + E\, n_{P_{ford}}} \quad (14)$$

E is given a special value when there are no passings of trains in the intermediate stations.

The above formula is applicable in all normal cases. But if it is question of a double line on which there are a great many passenger trains which are run in groups, the following formula is used :

$$I_t = \frac{1\,440 - \dfrac{n_{P ford}}{C_p}\left[I_{Abf_P} + I_p\,(C_p - 1) + I_{Abf_G}\right]}{n_{G_{ford}} - 1} \quad (14a)$$

Here :

C_P = number of passenger trains in the group;

I_{Abf_P} = interval of the despatch of the passenger train after the goods train;

I_P = interval between the despatching of the passenger trains in the group;

I_{Abf_G} = interval of despatching the goods train after the passenger train.

1. Installations of the reception sidings.

The output capacity of the reception sidings in a shunting yard must correspond to the passage capacity required of the lines running into the yard. This concordance must consist in part of the fact that the useful length of these lines must correspond to the useful length of the main passing lines towards the intermediate stations of the line in question, but also in the fact that the shunting yard must be able to accept trains following each other according to the intervals on the diagram (T), or in the case of double lines, the interval I between trains.

It may be objected, against what we have just said, that on single lines, the trains may follow each other not only at intervals equal to the diagram period for the limit spacing of the stations (T_{begr}) but also at the interval between trains (I).

This is true, but only in the case of two trains, or three at the most, and never when there is a higher number, as when discussing the number of tracks in the intermediate stations, on a single line, we saw that with a diagram for pairs of trains, the successive trains can only run, in theory, at the time interval T_{begr}. As a result, if two or three trains, owing to some incident, run not at the spacing T but at the spacing I or T_{begr}, it is obvious that during the time 2 T or 3 T none of the succeeding trains should enter the shunting yard.

On a single line, the number of sidings in the reception group must be sufficient to take trains spaced at T minutes, which also determines the operating regime of the line, which the operators must observe. As the length of time the train stands in the reception sidings after arriving at the shunting yard is equal to t_{zer} the number of sidings (G_x) amounts to :

$$G_x = \frac{t_{zer}}{T_x} \tag{15}$$

For the reasons given above, the result should be rounded off to the next highest number.

If, in the case of incidents, during the time t_{zer} there were more than G successive trains in a group, in other words G + 1, G + 2 for example, it is obvious that all the trains over and above would not normally come into the shunting yard but would stop before it until the entry tracks were cleared.

As a result the time T determines not only the number of sidings needed in the shunting yard for the line in question, but also, for the dispatcher, the operating regime of successive trains on the section in question.

For a double line, there is the expression :

$$G_x = \frac{t_{zer}}{I_x} \tag{16}$$

Here again, we work on the time I minutes in which the trains follow each other, which is dictated by traffic requirements, but not with the time I′ minutes, which is possible because of the real passage capacity of the line. Now as $I' \leqslant I$, it being impossible for I′ to be greater than I, it can be taken that the trains also run at an interval of I′ minutes, on condition that during the time t_{zer} a group of trains does not consist of more than G. All trains over and above G will necessarily have to wait outside the shunting yard, which may be particularly disadvantageous when the intermediate stations are not equipped to allow trains to pass each other.

If, for each line, we have calculated the number of tracks required, the total number of entry sidings at the shunting yard (ΣG) must correspond to the following relation :

$$\Sigma G = G_1 + G_2 + ... + G_n \tag{17}$$

The length of each group of these reception sidings must correspond to the maximum length of the train on the part section concerned (L_{Nu}), including the length of the shunting locomotive in the shunting yard itself, or the maximum length of the trains (L_{Nu}) on the part sections concerned (interchangeability of the tracks).

Certain people, however, are also of the opinion that in a reception group of sidings leading to the gravity hump, the useful length of the sidings should be greater than the maximum length of the trains. It is necessary, in fact, to assure a sufficient margin of safety in connection with work at the hump, in other words, it must be possible to allow train to come into the reception sidings simultaneously with working on the hump, i.e. shunting the wagons. Such a result can be obtained by lengthening the reception sidings, which assures that there will be a space between the end of the stopped train and the wagons geing pushed up to the hump. The length of this space depends on a great many conditions (slope of the line before entering the shunting yard, method of braking the train, percentage of wagons with brakes in the rake).

Here again, it may be necessary to install a track for the locomotives, a repair siding, a siding for service wagons, etc. There is no doubt about such things being necessary, but for the moment we will leave such problems aside.

Others think that the result of the calculation of the number of sidings required (G_x) from the expression (15) should not be rounded off to the next highest number, but merely to the result of the expression (17), which will give a smaller number of sidings required. We do not think this is to be recommended, however, but if it is desired to proceed in this way on certain lines (for example those with little traffic) and if these come to a total of q, it is necessary to proceed as follows :

a) calculate for these lines with little traffic the diagram period T for the passing capacity required in a special way from the following expression :

$$T = \frac{1\,440}{\dfrac{n_{G_{ford}} + E\, n_{P_{ford}}}{q}} \qquad (17a)$$

In this formula $n_{G_{ford}}$ and $n_{P_{ford}}$ represent respectively the sum of the number of goods trains and the equivalent passenger trains on these lines, and q the number of the latter;

b) without interrupting the traffic on these lines, have it regulated by a despatcher, especially the running of the goods trains, who will co-ordinate their running so as to assure that they will arrive at the shunting yard in proper order at intervals of T_x minutes, in other words in such a way that during this interval only G trains will arrive.

The number of sidings G for these lines must also be calculated from the expression (15) and the result must always be rounded off to the next highest number.

2. Installations of sidings for shunting.

a) *Siding installations for breaking up trains with a separate departure group of sidings.*

In dividing up the work of shunting on the system, the lots to be formed at each shunting yard from the traffic arriving are determined and exactly defined. From these lots, the yard makes up trains which may consist of a single lot or several lots.

In principle, two lots are laid down for each direction, one of traffic for the

stations on the line, the other of through traffic for the following shunting yard. When the daily goods traffic is considerable, each of these lots may be subdivided into several lots. In the same way, if the goods traffic is small, one train a day, it may be decided that the traffic for the section and the through traffic will be sent on in a single lot. Provisionally, there is no question of it being possible to decide on the classification of the elements in the same lot; we will return to this later.

If the shunting yard sends on trains formed of several lots, the number " m " of the expression (12) no longer represents the average number of wagons of a train but that of the wagons of a lot.

Consequently, when considering the work of the shunting yard (service station) defined according to the total work of shunting throughout the system, it is necessary to determine the number of lots made up in this yard.

Amongst the lots made up in the shunting yard, the following also have to be taken into account :

a) empty wagons classed by series if the shunting yard is used to garage empty wagons, or if it forms through trains from a given series of wagons from the mass of empty wagons passing through;

b) local traffic for the shunting yard itself ($U_{Ent} + U_{le}$), possibly classed according to the handling point. Wagons that must pass through the customs, wagons for reconsignment, and similar (transhipment, weighing) must be included amongst this local traffic, although such categories do not represent a special lot as regards the handling points;

c) wagons requiring current repairs which means that they have to be uncoupled (U_{Ausb}) (repairs to wagons, adjustments to their loads, disinfection, etc.) may form one or several lots;

d) so called " back shunted " wagons ($U_{Rück}$) i.e. all the wagons which change their direction of running at the shunting yard, and which, owing to the arrangement of the sidings or the method of working, have to be sorted or grouped twice.

In bilateral shunting yards, all the lots enumerated here may be doubled.

The determination of the number of lots (k) is of value because it is from the number of lots and their size each day that the number of sidings and their length in the marshalling installations are determined according to the principle " one siding for each lot "; on the other hand the exact determination of the number of lots (k) is of importance in determining the time needed to accumulate the wagons (t_{Ans}), seeing that there must be an average of m wagons collected into a lot before the train can be made up.

The average time needed to accumulate the wagons (t_{Ans}) may be determined from the following expression :

$$t_{Ans} = \frac{12\,m\,(k - 1.6)}{N_{Ges}} \qquad (18)$$

In the above expression, by N_{Ges} is to be understood not only the total number of wagons which run through the marshalling yard in the 24 hours, but this figure increased by the number of wagons which are shunted several times for grouping them, so that the time of accumulation

depends upon this latter number. Here we have :

$$N_{Ges} = N + (U_{Ent} + U_{le}) + U_{Ausb} + U_{Rück} \qquad (19)$$

In the shunting installations, k sidings are therefore necessary, in other words k must be equal to the number of lots made up by this shunting yard. The useful length of these sidings must agree with the length of the main tracks of the intermediate stations on the corresponding sections of line (L_{Nu}) or again, with the average number of wagons in a lot " m ", but taking into account the irregularity in the work between the moment when the m wagons have been grouped for a lot or a train and that when these wagons are drawn away to be sent out, as a function of the time of departure of the train.

If we remember that irregularities, in fact the impossibility of making each wagon touch the next on the shunting siding, mean that the length of this siding must be increased, it is possible, taking account the coefficient of user of the line, to determine this length by means of the expression :

$$L_x = \frac{L_{Nux}}{\gamma} \text{ metres} \qquad (20)$$

or :

$$L_x = \frac{m_x \cdot l_W}{\gamma} \text{ metres} \qquad (20a)$$

b) *Installations of shunting sidings without separate departure sidings.*

In this case, the shunting sidings are also used as departure sidings.

All that has been said so far about the number of lots or sidings (k), the average number of wagons in the train or in the lot (m) as well as the determination of the total number of wagons to be accumulated (N_{Ges}) remains valid in this case also. The only modification is due to the fact that the shunting sidings should be longer because at the moment when a sufficient number of wagons have been collected for the train or lot, the train or lot will not leave immediately as it would if there were a departure group of sidings; first of all, the train has to be classified into the order of stations (section train) and the statement prepared, the documents sorted, the brakes tested, the train sent out, etc. During this time, wagons continue to arrive, so that there must be sufficient room on the siding to accumulate and send them on. The question which arises is to know how long this time is, so as to be able to determine the necessary length of sidings.

The time required to accumulate the wagons (t_{Ans}) can be precisely defined. At the end of this period, the last wagon has arrived on the reception sidings. The wagons remain on this group of sidings until they are distributed over the shunting sidings, in other words during the time (t_{Zer}); they remain in the shunting sidings until the train leaves ($t_{Zus} - t_{Zer}$). Consequently, if the time the wagons remain in the shunting yard, which is composed of the time of accumulation (t_{Ans}) and the time riquired to make up the Train (t_{Zus}) to which must also be added the time to shunt the trains coming in, amounts to a total of t_{tech}, the departure siding must be lengthened by the amount needed to take the wagons arriving in the marshalling yard during the time $t_{Zus} - t_{Zer}$, or $t_B = t_{Zus} - t_{Zer}$.

This length may vary for different lots and depends upon the magnitude of m and the daily movement in wagons for this lot (N_x). The needed length is determined by the following formula :

$$L_x = \frac{\left[m_x + \frac{N_x\,(t_{zus} - t_{zer})}{24}\right] \cdot l_W}{\gamma} \qquad (21)$$

The coefficient $\gamma < 1$ takes into account both irregularity in working and the fact that the wagons do not come into contact during shunting. We will provisionally take $\gamma = 0.7$.

With a very numerous lot, we may get the following case :

$$L_x = \text{about } 2\, L_{Nu}. \qquad (22)$$

In such a case, it would be necessary to have or make an enormously long siding, which in any case is neither possible nor desirable. For the lot in question it, would be necessary to have or make two sidings L_{Nu} or $\frac{L_{Nu}}{\gamma}$ metres long.

In yards of this kind, however, there may be other reasons making it necessary to double the number of sidings for the same lot.

On the one hand, if the train leaves in the opposite direction to which it was marshalled; in principle, it is necessary to have two sidings for each lot which leave in the opposite direction to that in which they were marshalled. Doubling of the sidings is essential. Whilst the wagons that have been accumulated are used to make up a train, wagons from the same lot continue to arrive and parking them on the same siding gives rise to difficulties.

The useful length of these sidings should in principle agree with the following expression :

$$L_x = \frac{L_{Nux}}{\gamma} \qquad (22a)$$

Moreover, if they leave in the same direction in which they were shunted, but the trains are sent out composed of several lots, it is not necessary for all the sidings to be both shunting sidings and departure sidings. Some of them may simply be used for shunting and consequently have a length of $\frac{m_x \cdot l_W}{\gamma}$ metres, whilst the others which are used both for shunting and departure, will be L_{Nu} metres long and should be doubled. If it is not possible to double these latter, the length of such a siding should satisfy the following expression :

$$L_x = \frac{L_{Nu} + \frac{N_x\,(t_{zus} - t_{zer})}{24} \cdot l_W}{\gamma} \qquad (23)$$

But if the train leaving in the opposite direction to that in which shunting took place is combined with others, i.e. if a train is sent off composed of several lots, it is not necessary to double all the sidings corresponding to these lots. A certain part of the sidings can be used exclusively for shunting, need not be doubled and may have a length of $\frac{m_x \cdot l_W}{\gamma}$, whilst the other part used both for shunting and despatching must be double and have a length of :

$$L_{Nu} \text{ metres} \qquad (23a)$$

3. Installations of sidings of the departure group.

The departure group of sidings must fulfil the same conditions as the arrival group. It must correspond to the sections of line leaving the shunting yard. In the same way, it must allow of the full utilisation of the capacity of the lines in the intervals between the passenger services, and consequently it must, in the necessary time (T) or (I) allow successive trains to be sent on for each section. For each single line section, therefore, it is necessary to determine the time T from expression (13) and for each double line section, the time I_t from the relation (14) or (14*a*).

As the time taken to make up and send forward a train is $t_{Zus} - t_{Zer} = t_B$ the number of sidings amount respectively to :

$$G_x = \frac{t_B}{T_x} \text{ or } G_x = \frac{t_B}{I_x} \qquad (24)$$

or :

$$\Sigma G = G_1 + G_2 + ... + G_n \qquad (25)$$

The length of the sidings in the departure group must coincide with the maximum length of the trains on the corresponding lines, in other words amount to L_{Nu} metres.

4. Installations of sidings for the transit group.

In a shunting yard, it is also possible to use for this work the track installations intended for the entry and departure of the passenger trains. If this is not possible (separate stations or any other reason), there must also be sidings for the transit group of sidings.

This group has to assure the passing of a considerable number of through trains from all the lines. Their number may be greater or smaller, but it is necessary to base requirements on the greatest possible daily number of trains.

The number of trains in transit amounts to $\frac{U_{Tr}}{m}$; there must therefore be a sufficient number of sidings to take this number and for the time t_{Tr} (time a train in transit stands in the shunting yard). The number of sidings required can be obtained from the expression :

$$G = \frac{U_{Tr} \cdot t_{Tr}}{24\, m} \qquad (26)$$

In all cases, there must be at least two sidings ($G \geqslant 2$), in other words, if there are few through trains, it must be possible for at least as many through trains as any of the intermediate stations can take to be dealt with, i.e. in view of the possible reciprocal exchange of wagons (with units already classified) two trains from different lines must be able to meet.

5. Installations of sidings for shunting local traffic.

Certain lots, for example local traffic to the shunting yard or next service station, wagons for unloading, for transhipment, for disinfection and for customs control, in other words, local traffic, must be classified before consignment or put in position or in the right order for the next stations or unloading points. The through traffic can also under certain conditions have to be shunted repeatedly. This may be the case because of the

technical regulations, i.e. when the train includes both heavy and light wagons, when there are consignments distributed according to certain conditions, when the brakes on the rake make it necessary, possibly, because of different couplings (automatic and otherwise), etc. The shunting yard must also have sidings to deal with this additional marshalling. Special sidings may also be constructed for this purpose. Usually, several short sidings are provided, whose overall useful length is one and a half times that of a train (L_{Nu}). But it is also possible to make use of available sidings in the shunting group — or in the combined shunting and departure sidings.

In fact, if the yard has G sidings in the shunting group, with a useful length of L_x metres, the following total useful length is available for additional shunting :

$$L = \frac{G - 1}{2} L_x + L_x = L_x \frac{(G + 1)}{2} \text{ metres.}$$

Taking it that $L_x = L_{Nu}$, it can be deduced that for $G \geqslant 3$ there is always $L \geqslant 2\, L_{Nu}$ and the condition set is fulfilled.

It is naturally easier to carry out additional shunting if there are more than three sidings. This reasoning is based on the following facts. At a given moment when the lot in question is to be shunted at once, the sidings are not completely full of wagons. It can be allowed that on the average, half of all the sidings are occupied by wagons. We exclude from this number the siding on which the lot now to be collected and sent forward is accumulated. This siding is taken as available capacity for shunting, and as a result the available capacity is sufficient when $G \geqslant 3$.

Example : Unilateral shunting yard M similar to that shown in figure 6.

1) Corresponding sections and amount of traffic on them :

M — A single line; $n_{P_{ford}}$ = 12 pairs;
E = 1.3; $n_{G_{ford}}$ = 9 pairs;

Fig. 6.

M — B single line; $n_{P_{ford}}$ = 10 pairs;
E = 1.2; $n_{G_{ford}}$ = 14 pairs;

M — C double line; $n_{P_{ford}}$ = 20 pairs;
C_p = 3; $n_{G_{ford}}$ = 20 pairs;

$I_p = 18$ min; $I_{AbfP} = 40$ min; $I_{Abft} = 10$ min.

2) Maximum amount of work in the yard M :

$U_{Ent} = 100$; $U_{le} = 80$; $U_{EinL} = 70$; $U_{Ausb} = 20$; $U_{Tr} = 350$; $U_{Rück} = 0$.

3) Standards :

$t_{zer} = 90$ min; $t_{zus} = 210$ min; $t_{Tr} = 100$ min.

4) Coefficients of user of the lines : the usual coefficients.

5) The maximum amounts of the currents of wagons per direction are shown in Table 1, hereafter.

6) The shunting problem for yard M is shown in Table 2.

It is a question of determining what sidings are necessary and their coefficient of user in the case of maximum work.

Remark : units drawn out :

from B to C.	350 wagons
from C to B.	400 wagons
Total	750 wagons.

In view of the way the yard is built, the units drawn out are marshalled directly; this gives $U_{Rück} = 0$.

Solution to the problem.

1) *Sidings for the reception of the trains.*

a) Calculation of the diagram period T or of the interval :

for the section M — A :

$$T_A = \frac{1\,440}{n_{G_{ford}} + E \cdot n_{P_{ford}}} = \frac{1\,440}{9 + 1.3 \cdot 12} = \text{about } 58.5 \text{ min.}$$

for the section M — B :

$$T_B = \frac{1\,440}{14 + 1.2 \cdot 10} = \text{about } 55.3 \text{ min.}$$

for the section M — C :

$$I_C = \frac{1\,440 - \dfrac{n_{P_{ford}}}{C_P}\left[I_{Abf_P} + I_P (C_P - 1) + I_{Abf_G}\right]}{n_{G_{ford}} - 1}$$

$$I_C = \frac{1\,440 - \dfrac{20}{3}\left[40 + 18\,(3 - 1) + 10\right]}{15 - 1} = \text{about } 62 \text{ min.}$$

b) Calculation of the number of sidings:

$$G_A = \frac{t_{zer}}{T_A} = \frac{90}{58} = 1.54 = \text{about 2 sidings}$$

$$G_B = \frac{90}{55.3} = \text{about 2 sidings}$$

$$G_C = \frac{90}{62} = \text{about 2 sidings}$$

$$G = 2 + 2 + 2 = 6 \text{ sidings.}$$

c) The useful length of these sidings is determined from the maximum length of the trains (L_{Nu}) on the corresponding sections. To allow the sidings to be interchangeable, it is necessary to use as a basis the section on which the length of the trains (L_{Nu}) is the greatest.

2) *Track installations for shunting and despatching.*

In agreement with the shunting problem, every day the following wagons have to be shunted :

$$N_u = N + U_{Ent} + U_{le} + U_{Ausb} + U_{Rück} = (1\,950 - 350) + 100 + 80 + 20 = 1\,800 \text{ wagons}$$

TABLE 1.

From \ To	A	B	C	M	Σ
A	—	100	300	50	450
B	150	—	350	50	550
C	250	400	—	100	750
M	50	50	100	—	200
Σ	450	550	750	200	1 950

TABLE 2. — **Shunting problems in yard M.**

Order	Lot	Maximum flow of wagons N_x	Daily number des-patched	Number of wagons per train des-patched	Remarks
1	Section - towards A	50	1	50	supplementary shunting
2	towards A - lot 1	150	3	50	
3	towards A - lot 2	100	5	20	sent on by the same train, but additional shunting of each lot separately
4	towards A - lot 3	150	5	30	
5	Section - towards B	30	1	30	supplementary shunting
6	towards B - lot 4	120	3	40	
7	towards B - transit	200	5	40	
8	towards B - lot 5	80	5	16	sent on by the same train, but additional shunting of each lot separately
9	towards B - lot 6	120	5	24	
10	Section - towards C	50	1	50	supplementary shunting
11	towards C - lot 7	200	4	50	
12	towards C - lot 8	250	5	50	
13	towards C - transit	150	3	50	
14	towards C - lot 9	100	2	50	
15	towards M - local with repairs	200	5	40	supplementary shunting
$\frac{15}{2}$	Total :	$\frac{1\,950}{350}$	$\frac{53}{8}$	35.5	

$$m = \frac{1\,950 - 350}{53 - 8} = 35.5 \text{ wagons.}$$

divided into thirteen lots. Additional shunting has to be done with :

$$50 + 30 + 50 + 200 = 330 \text{ wagons.}$$

The nominal number of wagons dealt with amounts to 1 800 + 330 = 2 130 wagons.

The nominal number of wagons in transit is $U_{Tr} = 350$ wagons.

Time required to make up a train : $t_{zus} = 210$ min = 3.5 hours.

Time needed to accumulate the wagons:

$$t_{Ans} = \frac{12\,m\,(k - 1.6)}{N_u}$$

$$= \frac{12 \cdot 35.5\,(13 - 1.6)}{1\,800} = 2.7 \text{ h.}$$

Time the wagon stands on the siding during reforming :

$$t_{um} = t_{zus} + t_{Ans} = 3.5 + 2.7 = 6.2 \text{ h},$$

$$t_{Tr} = \frac{100}{60} = 1.66 \text{ h.}$$

Calculation of the average time a wagon stands in the yard M :

	1 600 · 6.2 =	9 920 wagon-hours
	350 · 1.66 =	581 wagon-hours
in all :	1 950 wag.	10 501 wagon-hours

$$t_{tech} = \frac{10\,501}{1\,950} = 5.39 \text{ h (standard).}$$

The number of sidings required for shunting and sending forward amounts, according to the shunting problem, to G = 13 sidings.

From the problem, the amount of work and the construction of the station, it results that the trains leave in the opposite direction to that of shunting, so that in principle sidings Nos. 1, 2, 3 and 4 should be doubled. As lots 3 and 4 leave on the same train, it is unnecessary to double one of sidings 3 or 4.

Consequently, the number of sidings needed $G = 13 + (4 - 1) = 16$ sidings, namely 14 sidings for shunting and despatching, and 2 shunting sidings.

Lots 8 and 9 are also sent forward by the same train. Consequently, one of these sidings can be a purely shunting siding (see diagram and Table 3).

The lengths shown are the necessary useful lengths. The real length of the sidings depends upon the mutual connections.

3) *Track installations for the transit group.*

As $U_{Tr} = 350$ wagons, $t_{Tr} = 1.66$ hours

and $m \dfrac{5 \cdot 40 + 3 \cdot 50}{5 + 3} = 43.8$, we get :

$$G = \frac{U_{Tr} + t_{Tr}}{24\,m} = 0.55.$$

In this case we will take G as equal to 2 sindings.

4) *Track installations for supplementary shunting.*

50 + 30 + 50 + 200 = 330 wagons have to be shunted a second time. In the shunting and forwarding installations, we have :

$$L = L_x \frac{(G + 1)}{2} \text{ metres,}$$

$$L_x = \frac{11\,169}{16} = 700 \text{ m,}$$

$$L = 700 \frac{(16 + 1)}{2} = 5\,950 \text{ m.}$$

TABLE 3. — **Calculation of the useful length of the different sidings.**
(Hypothesis L_{Nu} = 550 m or in the case of section B: 450 m).

Shunting problem No.	Number of sidings needed		Calculation from expression No.		Length of sidings needed
	Shunting and despatch	Shunting			metres
1	2	3	4	5	6
1	2	—	20	$2 \cdot \frac{L_{Nu}}{\gamma} = 2 \cdot \frac{550}{0.7} \simeq 1\,570$	1 570
2	2	—	20	$2 \cdot \frac{550}{0.7} \simeq 1\,570$	1 570
3	—	1	20*a*	$\frac{m_x \cdot l_w}{\gamma} = \frac{20 \cdot 10}{0.7} \simeq 286$	286
4	2	—	23*a*	$2 \cdot L_{Nu} = 2 \cdot 550$	1 100
5	1	—	21	$L_x = \frac{\left[m_x + \frac{N_x (t_{zus} - t_{zer})}{24}\right] \cdot l_w}{\gamma} = \frac{\left[30 + \frac{30(3.5-1.5)}{24}\right] \cdot 10}{0.7} \simeq 465$	465
6	1	—	21	$L_x = 715$	715
7	—	—	—	transit	—
8	1	—	23	$L_x = \frac{L_{Nu} + \left[\frac{N_x (t_{zus} - t_{zer})}{24}\right] \cdot l_w}{\gamma} = \frac{450 + \left[\frac{80(3.5-1.5)}{24}\right] \cdot 10}{0.7} \simeq 735$	735
9	—	1	20*a*	$\frac{24 \cdot 10}{0.7} \simeq 343$	343
10	1	—	21	$L_x = 775$	775
11	1	—	21	$L_x = 955$	955
12	1	—	21	$L_x = 1\,010$	1 010
13	—	—	—	transit	—
14	1	—	21	$L_x = 835$	835
15	1	—	21	$L_x = 810$	810
—	14	2	—	total	11 169

This length is quite adequate for shunting, i.e. for making up the trains that pick up wagons, or for shunting the local traffic apart from the transhipment sidings.

5) *Use of the sidings in the case of maximum work.*

Useful length of sidings for the reception of trains :

$$6 \cdot 550 = 3\,300 \text{ m.}$$

According to Table 3, the useful length of sidings for shunting and forwarding amounts to 11 169 m.

Average number of wagons in the case of maximum work :

$$1\,950 \cdot \frac{5.39}{24} = 440 \text{ wagons.}$$

The average coefficient of user in the case of maximum work is :

$$\frac{440 \cdot 10}{11\,169 + 3\,300} = 0.32.$$

D. PASSENGER STATIONS

In the passenger stations, there are two categories of lines : arrival and departure lines, and the sidings, i.e. lines on which the passenger rakes are garaged whilst they are being washed, cleaned and got ready for their following journey.

1. Calculation of the capacity of the arrival and departure sidings.

The following factors are considered to be the most important ones in this case:

a) number of trains arriving which are divided up in the station in question (n_{ank}) as well as the time the arrival and departure lines are occupied by the train sent forward (t_{abf});

b) number of trains running through the station, with or without being reformed (n_{Tr}) as well as the length of time the train occupies the line when passing through (t_{Tr});

c) irregularities in the running of the trains according to the time of day, i.e. the ratio between the peak traffic and the average traffic ($\beta > 1$);

d) time the lines are used during the day $T - t$ hours. For example in the large cities, the passenger stations are not used in the morning between midnight and 5 a.m., which also has to be taken into account; we therefore get :

$$T - t = 24 - 5 = 19 \text{ hours.}$$

After determining all the above factors, the total time of occupation of the lines by trains arriving, leaving or running through the station has to be calculated. But it should be noted that amongst the trains arriving and leaving, and still more amongst those passing through, there are some which remain at the station different periods. We therefore get :

$$\Sigma n_{ank} \cdot t_{ank} = n_{ank_a} \cdot t_{ank_a} + n_{ank_b} \cdot t_{ank_b} + \ldots\, n_{ank_n} \cdot t_{ank_n} \tag{27}$$

$$\Sigma n_{abf} \cdot t_{abf} = n_{abf_a} \cdot t_{abf_a} + n_{abf_b} \cdot t_{abf_b} + \ldots\, n_{abf_n} \cdot t_{abf_n} \tag{28}$$

$$\Sigma n_{Tr} \cdot t_{Tr} = n_{Tr_a} \cdot t_{Tr_a} + n_{Tr_b} \cdot t_{Tr_b} + \ldots\, n_{Tr_n} \cdot t_{Tr_n} \tag{29}$$

$$\Sigma\Sigma\, n \cdot t = \Sigma n_{ank} \cdot t_{ank} + \Sigma n_{abf} \cdot t_{abf} + \Sigma n_{Tr} \cdot t_{Tr} \tag{30}$$

The number of lines required is determined with the aid of the following relation :

$$G = \frac{\Sigma\Sigma n \cdot t \cdot \beta}{T - t} \quad (31)$$

It is also necessary to determine the length of the longest line and that of the shortest line, or again the lengths of the various lines. For this, the longest and shortest rakes are taken as the basis, or the length of the different rakes to be expected, with possibly some margin.

2. **Calculation of the capacity of the garaging sidings.**

To calculate this capacity, it is necessary to know, in addition to the number of rakes (n_{ank} or n_{abf}), the length of these rakes, i.e. the number of axles or number of coaches in each rake (m_a, m_b .... m_n).

It is also necessary to know the average length per axle (or per coach) l_W in metres, the coefficient of user of the lines, $\gamma < 1$, as well as the average time the rakes spend on the garaging sidings (t_{Abst}).

The length, expressed in metres, is obtained with the aid of the relation :

$$L_{Einst} = \frac{n_a \cdot m_a \cdot l_W \cdot t_{Abst_a} + n_b \cdot m_b \cdot l_W \cdot t_{Abst_b} .... + n_n \cdot m_n \cdot l_n \cdot t_{Abst_n}}{24\,\gamma} \quad (32)$$

This relation gives the necessary length in metres. The length of the lines must be m, and, if it is theoretically possible, there must be a special siding for each rake. If absolutely necessary, a siding can also be enough for two or three small rakes.

Example : Passenger station N.

Number of trains arriving :

$$n_{ank} = 40,$$

of which :

$$n_{ank_a} = 20; t_{ank_a} = 0.5\text{ h},$$
$$t_{ank_b} = 10; t_{ank_b} = 0.3\text{ h},$$
$$n_{ank_c} = 10; t_{ank_c} = 0.2\text{ h}.$$

Number of trains leaving :

$$n_{abf} = 40; t_{abf} = 0.4\text{ h}.$$

Number of trains passing through :

$$n_{Tr} = 6 \qquad t_{Tr} = 0.2\text{ h}.$$

Irregularities in the running of the trains :

$$\beta = 2.5.$$

Average composition of the rakes and time they remain on the arrival and departure lines :

$$n_a = 20, m_a = 10, t_{Abst_a} = 8\text{ h};$$
$$n_b = 10, m_b = 5, t_{Abst_b} = 6\text{ h};$$
$$n_c = 10, m_c = 5, t_{Abst_c} = 4\text{ h}.$$

Length of a coach $l_W = 25$ m.

Coefficient of user $= 0.8$.

Calculation.

1. **Track installation for reception and dispatch.**

$$\Sigma n_{ank} \cdot t_{ank} = 20 \cdot 0.5 + 10 \cdot 0.3 + 10 \cdot 0.2 = 10 + 3 + 2 = 15 \text{ trains/hours},$$
$$\Sigma n_{abf} \cdot t_{abf} = 40 \cdot 0.4 = 16 \text{ trains/hours},$$
$$\Sigma n_{Tr} \cdot t_{Tr} = 6 \cdot 0.2 = 1.2 \text{ train/hour},$$
$$\Sigma\Sigma\, n \cdot t = 15 + 16 + 1.2 = 32.2 \text{ trains/hours}.$$

Number of lines :

$$G = \frac{\Sigma\Sigma n \cdot t \cdot \beta}{T - t} = \frac{32.2 \cdot 2.5}{24 - 4} = 4.02 \text{ tracks.}$$

Hypothesis : 4 lines.

Useful length of lines :

maximum :

$$m_a \cdot l_W \cdot 1.2 = 10 \cdot 25 \cdot 1.2 = 300 \text{ m},$$

minimum :

$$m_b \cdot l_W \cdot 1.2 = 5 \cdot 25 \cdot 1.2 = 150 \text{ m}.$$

Increased by 20 %.

2. Track installations for garaging and cleaning passenger coaches.

$$L_{Abst} = \frac{n_a \cdot m_a \cdot l_W \cdot t_{Einst_a} + n_b \cdot m_b \cdot l_W \cdot t_{Einst_b} + \dots n_n \cdot m_n \cdot l_W \cdot t_{Einst_n}}{24\,\gamma}$$

$$L_{Abst} = \frac{20 \cdot 10 \cdot 25 \cdot 8 + 10 \cdot 5 \cdot 25 \cdot 6 + 10 \cdot 5 \cdot 25 \cdot 4}{24 \cdot 0.8} = \text{about } 2\,720 \text{ m}.$$

The number of sidings must be calculated taking into account the given lengths or rakes :

$$20 \text{ rakes each } \frac{10 \cdot 25}{0.8} = 312 \text{ m length.}$$

$$20 \text{ rakes each } \frac{5 \cdot 25}{0.8} = 156 \text{ m length.}$$

$$G = \frac{2\,720}{312} = \text{approximately 9 sidings,}$$

with a useful length of at least 300 m.

GENERAL REMARKS.

1) In this report, we have only used general hypotheses as a basis and proposed ways of solving so-called typical cases.

However, there may be such cases as a station being used both as an intermediate station and as the starting or terminal station for the passenger traffic, the latter being of greater or lesser importance (stopping trains). They may also have to handle the goods in the wagons. In cases of this sort, great prudence must be exercised. In any case, the station must have the necessary track installations, on the one hand, as an intermediate station for the line in question and, on the other, as a passenger station in which trains come up to the platforms, are formed and shunted, or as a goods yard in which the goods trains are formed with local units or shunted. It is possible in such a case that the lines used to carry out the function of an intermediate station, can be used at the same time for the arrival and departure lines for the passenger traffic, or that the sidings intended for the formation and shunting of the goods trains can also be used for the passenger traffic and vice versa.

One special case is that of stations lying at the junction point of several lines, where trains converge that have to make connection with each other (passenger trains) or trains which have to exchange wagons. A station of this kind must in any case have the same installations for passing trains as intermediate stations on the corresponding lines.

In both cases, the role played by the station must be taken into account and the character of the traffic on the connecting lines, as well as the importance of the goods traffic as regards wagon exchanges in such stations, and the shunting sidings must be calculated on this basis.

In the case of stations at the ports and similar, the principles outlined above will be applied, taking into account the work they have to carry out.

2) To end, we must say a few words about the subject of the coefficient γ, the so-called coefficient of user of the sidings.

In this coefficient, the following can be taken into account :

a) handling the wagons without reciprocal interferences (intermediate stations and goods yards), handling in the wagons $\gamma = 0.7$ to 0.9.

b) necessity to be able to make up and split up the trains (goods yards — arrival and departure lines) $\gamma = 0.5$;

c) irregularities between the accumulation of wagons and their departure owing to running groups of passenger trains over the line and the impossibility of accumulating wagons several times (shunting yards, shunting and forwardind sidings) $\gamma = 0.7$ to 0.9;

d) possibility of shunting the passenger trains (passenger stations — garaging sidings) $\gamma = 0.7$ to 0.8.

The above coefficients have all been found to be accurate only within certain limits. Owing to the averages available, they have been given values somewhat arbitrarily.

3) In general, the coefficients of irregularity are not taken into account in the calculation, for the reason that all the values which make the work vary are taken at their maximum value, i.e. the figures for the most unfavourable cases. The only exception is in the calculation of the groups of sidings for incoming and departing trains in the case of passenger traffic where, although the maximum possible number of trains has been used as the basis (n), one has adopted as coefficient of irregularity according to the time of day $\beta > 1$, and for coefficient of irregularity as regards the length of the trains $\gamma = 1.2$ in the calculation of the incoming sidings.

In these considerations, no account has been taken, in particular, of such problems as so-called locomotive sidings, turn-outs needed, etc. For the moment, we have no intention of embarking upon the study of such problems, and we have acted accordingly.

We hope that these considerations will prove useful to those dealing with the questions concerned.

[625 .14 (01]

The effect of suspension design on rail stresses.

The matching of spring stiffness and damper characteristics as an aid to improving riding and reducing rail stresses,

by J. L. KOFFMAN.

(*The Railway Gazette*, March 27, 1959).

The stresses caused by pressures at the point of contact between the periphery of circular or spherical bodies were first theoretically examined by H. Hertz (1). As far as the particular problem of stresses at the point of contact between wheel and rail is concerned, attention should be drawn to the work due to Beliaev whose papers (2) are of fundamental interest. Although some of the results were mentioned by Timoshenko (3), Beliaev's extensive work on the subject of wheel and rail contact stresses is practically unknown in this country. Briefly, Beliaev has originally shown that the point of dangerous stress is below the head surface of the rail and that the magnitude of the stress is :

$$\delta_1 \approx 0.6\ \delta_{max}$$

The value of the maximum normal stress in the centre of the contact ellipse is given by :

$$\delta_{max} = m_q \sqrt[3]{PE^2/R^2}$$

where P is the load, E the modulus of elasticity and R the wheel radius. The value of m_q depends on R and also on the rail head radius r, the relevant values being given below :

r/R	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.15	0.1
m_q	0.388	0.4	0.42	0.44	0.468	0.49	0.536	0.6	0.716	0.8	0.97

Brief reflection shows that the stresses are not inversely proportional to the wheel radius and that the ratio r/R is of considerable importance. It also will be noted that an appreciable change in wheel radius will be required to ensure a worthwhile reduction of the contact stresses. As already mentioned by Beliaev, « to reduce this stress by increasing the wheel radius is extremely unprofitable and is practically almost impossible », but other ways of attack are indicated via improved quality of the rail steels or by increasing the railhead radius, or both. In addition, the possibilities of reducing the dynamic loads imposed by the vehicle on the track merit serious consideration, and here attention must be paid to the allocation of the static deflections to primary and secondary suspension systems and to the magnitude of the damping forces.

Dynamic deflections.

The effect of the mass and static spring deflections, as well as of the damping, on the dynamic deflection of primary springs previously were considered in the case of a 100-ton Co-Co locomotive. (4) The dynamic deflections were plotted in terms of a magnification factor, i.e., the deflection of the

primary springs divided by the height of the « obstacle » or by the equivalent wheel displacement. It should be mentioned here that the path of the wheel passing over a rail joint cannot be considered as strictly equivalent to being caused by a descending or ascending step, but, as suggested by Inglis,(5) the rail joint may be likened to a concealed pothole, increased speeds reducing the descent of the wheel, the depression becoming shallower and longer. Inglis concludes that there is a critical speed at which rail joint impact is a maximum, but that this critical speed, like any maximum or minimum phenomenon, is not capable of exact experimental determination. It also should be added that the speeds at which such maxima are likely to occur will depend on vehicle and track design, i.e., upon vehicle masses, spring stiffness values and damping factors, as well as on certain leading vehicle dimensions on the one hand and on rail length and the dynamic characteristics of the permanent way on the other.

The loads imposed on the rails by moving vehicles will be the resultant of the static wheel load P_1, the additional dynamic load P_2 due to the unsprung mass, and the dynamic load P_3 due to the oscillations of the sprung mass. The value of P_2 will depend on a number of factors such as track irregularity at the rail joint, sprung and unsprung weights, mass and inertia of the track which takes part in the oscillations, its stiffness and the vehicle speed, as well as wheel diameter D. In addition, the stiffness of the various vehicle components, including the torsional and vertical stiffness of the motor drive with electric or diesel-electric vehicles is of considerable importance. Thus, the value of R_2 might be expected to increase as a function of speed,(6) but inversely proportional to D 1/2 and ρ 1/2, where ρ is a function of the track mass m_g taking part in the shock and reduced to the point of impact, and the unsprung weight. The value of m_g is not substantially affected by track parameters and some representative values are given in Ref.(7)

The spring characteristics of the track are made up of the stiffness of the rail, baseplate, sleeper and ballast, and as all these components act in series, the softest component — in this case the ballast — is the controlling factor, its stiffness being in the order of 250 to 750 ton per in.,(8) while the total track stiffness is about 125 to 250 ton per in.(7) The natural frequency of the track under load is of the order of 25 to 30 cycles per sec.,(9) so that resonance is not likely to occur here at present day speeds with the suspension system.

Axle-hung motors.

With axle-hung traction motors the magnitude of the hammer blow can be appreciably reduced by reducing the rotational acceleration of the armature subsequent to the vertical acceleration of the wheels. This can be achieved by introducing a certain amount of torsional resilience at the gear wheels.(10) The more recent development of the semi-axle-hung motor(11) also is a step in the right direction as far as the use of a simple drive resulting in reduced hammer blow effects is concerned. Generally, it is recognised that the unsprung masses result in the dynamic wheel-load increasing with speed, and it should be possible to evaluate this dependence numerically, provided the effective deviation of the track from the horizontal level at the rail joint, etc., is known. Once this is the case, the subsequent calculations of the amplitudes of oscillations of the sprung vehicle components and the accelerations and displacements of the unsprung masses readily can be determined.(12)

Because of this, it must be mentioned that the determination of the « effective obstacle» shape as encountered by vehicles of different types over a wide range of speeds at the rail joints and along the track should be considered as a pressing investigation relating to the interaction between vehicles and track. The investigations usually carried out along the lines of rail load determinations — and this without taking into account the finer points of vehicle and track dynamics — while providing an overall pattern of load magnitudes do not allow for the effect of vehicle design parameters. Apart from this, the effect of rail, etc., inertia, particularly at

high speeds, will lead to differences between the pattern of measured loads and the contact and shear stresses. The results are likely to encourage some and discourage others in a rather sweeping fashion, without providing clear and unambiguous guidance to the rational development of vehicles designed to achieve best all-round riding qualities of benefit to track, vehicles, passengers, and freight. Once the nature of the track inertia action and the magnitudes of the « obstacles » in terms of wheel displacement are known, the dynamics of vehicle behaviour should be susceptible to a more rational analysis of great benefit to designers and operators alike.

The effect of spring and damper characteristics on the dynamic loads due to the action of sprung masses may be considered for the case of a 100-ton bogie locomotive.(4) Assuming that the unsprung masses will be displaced by a certain amount when moving over rail joints, the resultant deflection of the primary springs can be determined from the previously plotted values of the magnification factor. Furthermore, since the force-displacement characteristics of the springs are also known, the deflections can be interpreted in terms of load imposed on the wheels in addition to the static load due to the sprung mass as represented by the static spring deflection. This has been done for the above-mentioned example, assuming an « effective » vertical wheel displacement of 0.25 in. The results are plotted in figure 1, this time in terms of dynamic load in tons versus speed in m.p.h. In addition to the data relating to bogies incorporating primary and secondary suspension, the results of calculations relating to vehicles fitted with primary suspensions only are given. This latter data can be readily obtained (13) and the conditions relating to rather heavy damping (D = 0.5), and a deflection of 3 in. is representative of steam locomotive practice. It should be stressed that these calculations refer only to bouncing oscillations and that the magnitudes of the load increments might be increased due to pitching and particularly due to swaying.(4)

The total wheel-load thus will depend on vehicle as well as track characteristics. It

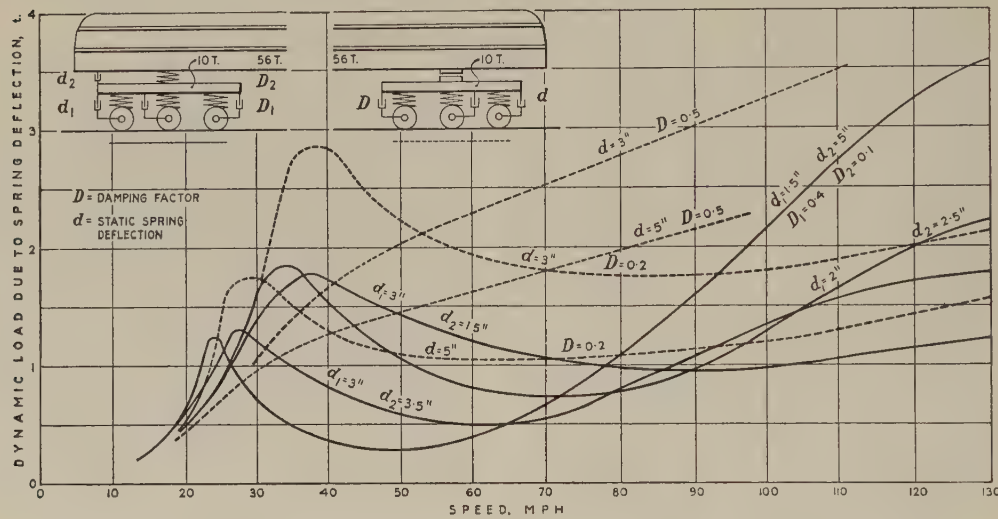

Fig. 1. — Dynamic wheel load due to spring deflection as a function of deflection distribution and damping factors.

will comprise the static load P_1, the dynamic augment P_2 due to the unsprung mass, and a further augment P_3 which will depend on the dynamic characteristics of the vehicle. The approximate dependence of the total wheel-load versus speed, which might be encountered in service, is plotted in figure 2. As indicated by the dotted curves, the final dependence will be appreciably influenced by P_2 and possibly to a lesser extent by P_3 and the condition may even arise when the total load, after an initially rapid rise, will rise very slowly until the second resonance condition is approached, which might be encountered at a relatively high speed.

The incidence of the rise of P_2 and P_3 to a certain extent will depend on track characteristics, particularly if their magnitudes are measured in terms of rail strain. Thus, a slowly moving vehicle will result in a certain amount of rail bending, the stress wave due to the wheel moving with it (9). As the speed increases, the mass of the rail, etc., will come into action resulting in lower deflection magnitudes. As the latter are measured to indicate stress this may approach a finite magnitude at a certain speed, while the rise of actual contact stresses with speed might follow a different course.

So far, the problems associated with dynamic wheel-loads have been considered solely from the point of view of track-loads.

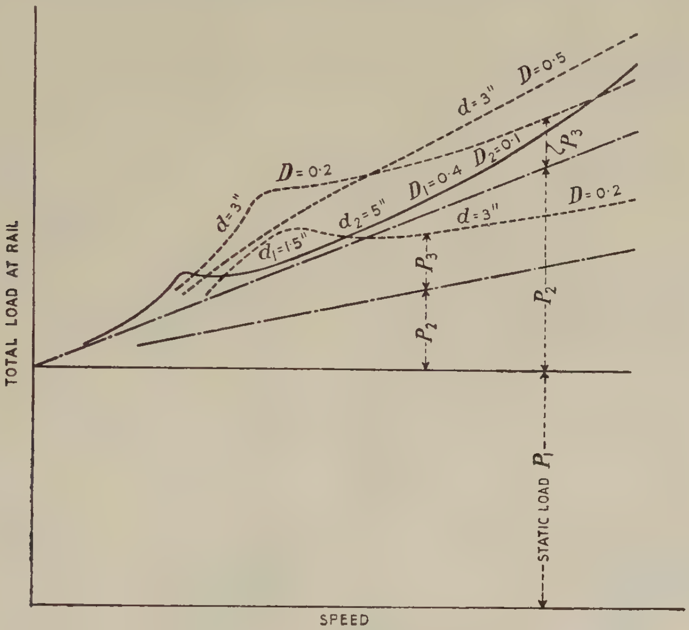

Fig. 2. — Possible effect of vehicle speed on total wheel load.

In terms of vehicle performance, it is necessary to consider the possibility of achieving optimum design solutions. This aspect of the matter will be briefly considered.

To simplify calculations dampers will be assumed to be present across the bolster suspension only. Also, to limit the scope of the considerations, only typical configurations will be dealt with. A persual of data relating to modern rolling-stock suggests that, for carriages, the ratio $\mu = m_1/m_2$, where m_1 is the sprung bogie mass and $2m_2$ the mass of the body, varies between 0.1 and 0.34 with 0.2 as a fair average. Similarly,

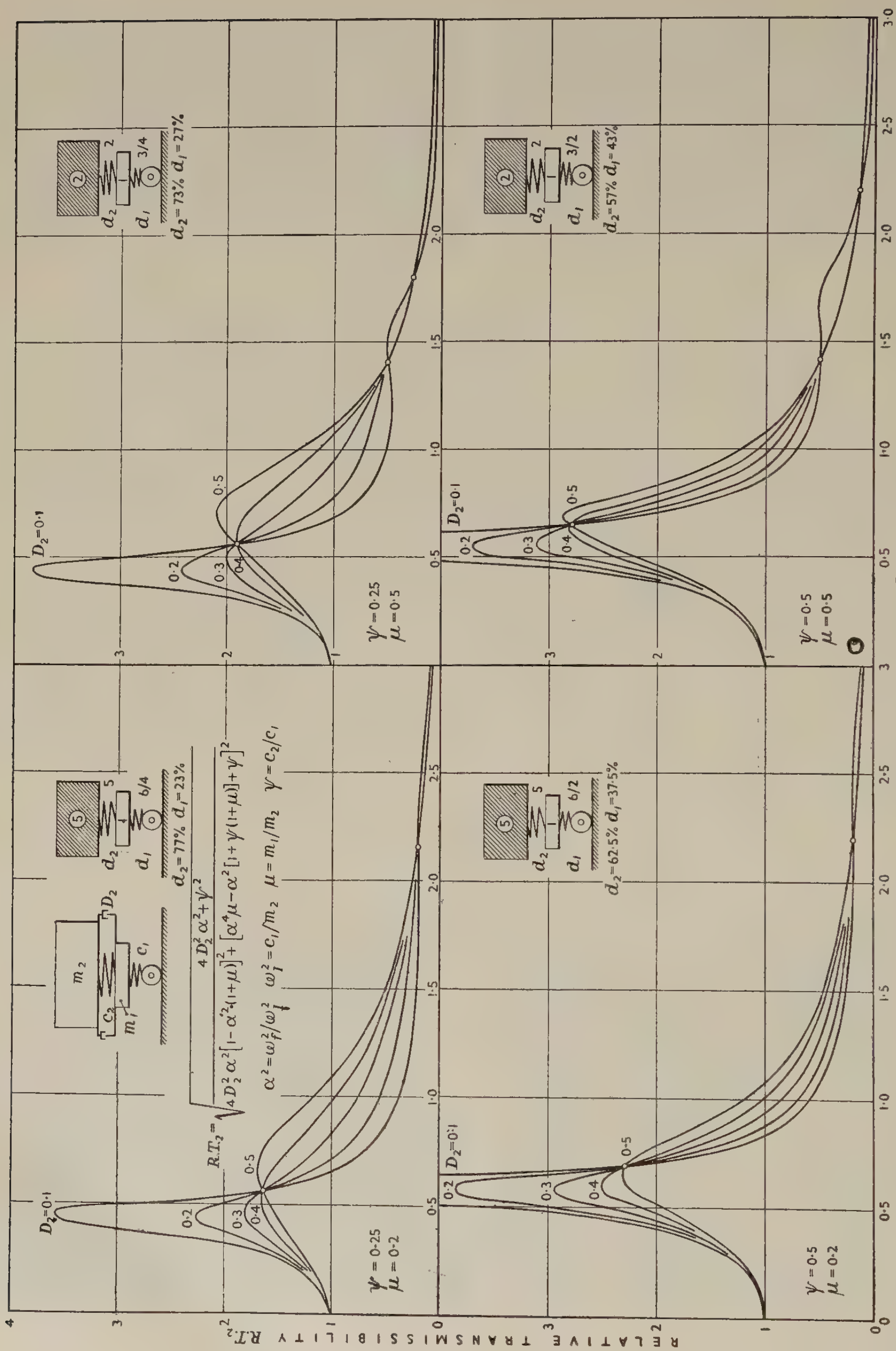

Fig. 3. — Effect of spring stiffness, mass ratio and bolster damping factors on body displacement relative to the ground.

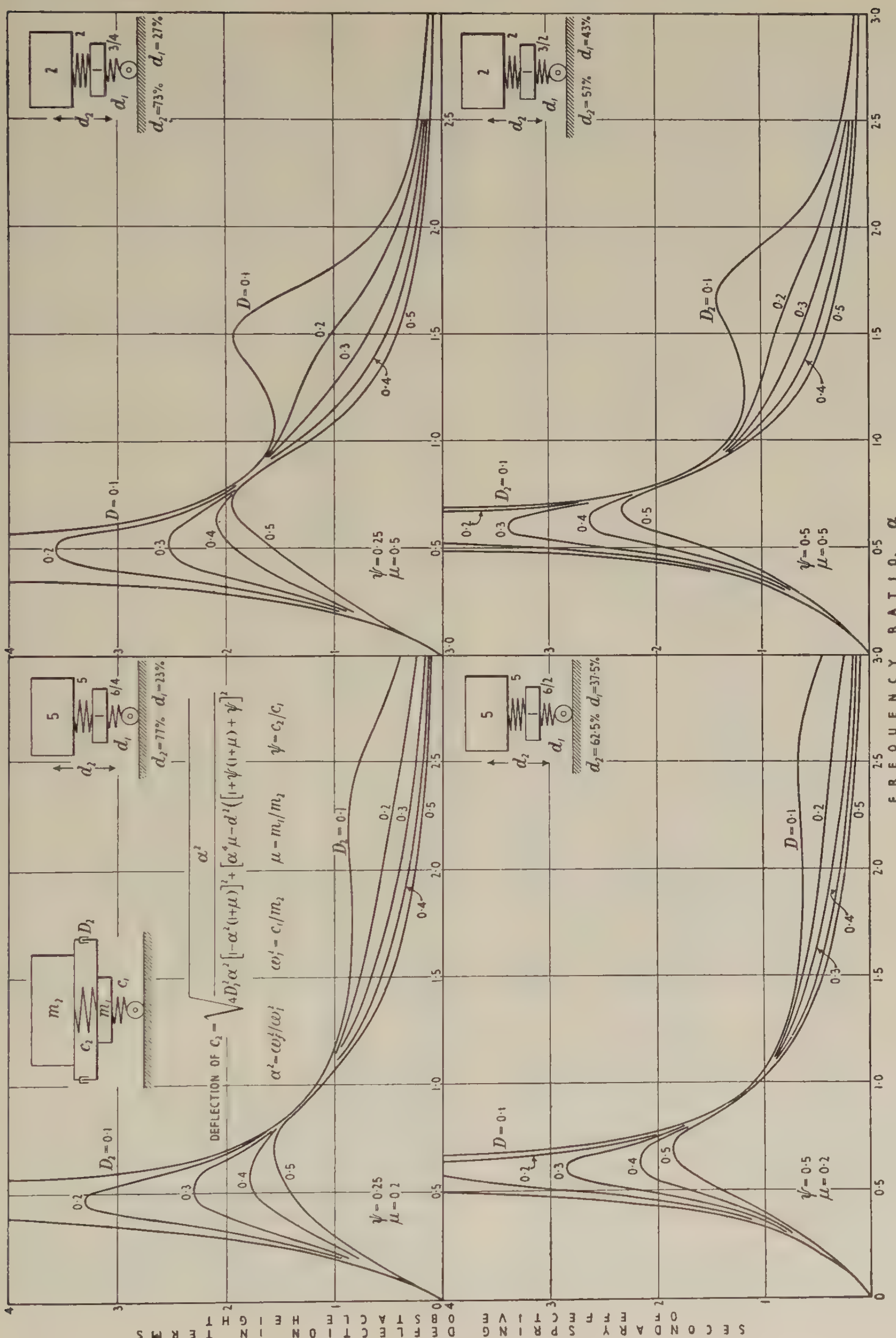

Fig. 4. — Effect of spring stiffness, mass ratio and bolster damping factors on the deflection of bolster springs.

for electric or diesel-electric bogie locomotives, μ varies between 0.1 and 1.1, the average values here being 0.2 and 0.5. The ratio of spring stiffness $\psi = c_2/c_1$, where c_1 is the stiffness of the primary suspension of one bogie and c_2 the stiffness of the secondary suspension of one bogie, for carriages varies between 0.34 and 1 with 0.5 as a fair average, while for bogie locomotives this value varies between 0.25 and 0.75, both 0.25 and 0.5 being representative values. With the aid of the necessary equations, which apply to bouncing only (14), it is possible to obtain the dependencies plotted in figures 3 to 6. The influence of the variables on the vertical displacement of the vehicle body in terms of the effective wheel displacement are plotted in figure 3.

Passenger vehicles.

In the case of passenger vehicles, comfort is generally of prime importance, so that here body displacement characteristics would be of over-riding importance. It will be noted that for $\mu = 0.2$ best results will be obtained with $\psi = 0.25$, *i.e.*, some 70 to 80 per cent of the total static deflection being allocated to the bolster springs. Also, as mentioned previously (13), the damping factor should have a value of about 0.2 to 0.25 of the critical value. While the difference between some of the curves might on first sight not appear as great, it must be stressed that in the frequency range concerned comfort will depend on the magnitudes of accelerations, i.e., displacement times the square of the frequency. If replotted on this basis, the difference will increase rather substantially.

The other aspect of the problem is shown by the curves, figure 6, of the dynamic deflection of the primary springs indicative of the dynamic load augment due to the sprung vehicle masses. To obtain the actual loads the magnitude of the wheel displacement must be multiplied by the magnitude of transmissibility, the product multiplied by the spring rate, and the results plotted along the lines of figure 1. It will be noted from figure 6 that, to reduce the dynamic load augment, it might pay to increase the static deflection of the primary springs of some systems at the expense of bolster spring softness, particularly with high μ-values. The desirability of maintaining damping factor values of 0.2 to 0.25 is apparent. Data relating to deflection characteristics of the bolster springs are plotted in figure 4; this should be of assistance when considering dynamic deflections, while the displacements of the sprung bogie components, i.e., frame, brake gear, etc., relative to the ground are plotted in figure 5. A comparison of these theoretically-derived values with published experimental results (15) suggests an encouraging similarity.

The above considerations indicate that, provided the mode of excitation is known, it should be possible to determine the loads imposed by the wheels on the track as a function of speed as well as vehicle and track design parameters. The tendency to correlate the complex relations in terms of simple rules expressed in terms of P_1/D (axle-load/wheel diameter) is understandable, but it can affect adversely the whole field of vehicle design and railway economics. The suggestion implied in an admittedly generalised P_1/D relation that the stresses imposed on the rail will decrease in inverse proportion with the wheel diameter is not strictly correct, while on the other hand increasing the wheel-diameter leads to difficulties, particularly with electric locomotives where current collection requirements set close limits to the roof height. Increasing the wheel diameter not only will increase the unsprung weight, but also will increase the moment of inertia of the bogie about the vertical axis. This in turn will increase the magnitude of the lateral impact (13) and with it the possibility of rail-corner shelling.

In any case this conception stated as a maximum value does not allow for the rail and tyre profile changes as the result of wear, nor does it take into account the statistical aspects of the stress distribution as imposed on the rails by the wheels carrying different loads at widely-varying speeds and by trains of varying load distribution. This is of particular importance when changing the type of traction when the number of locomotives

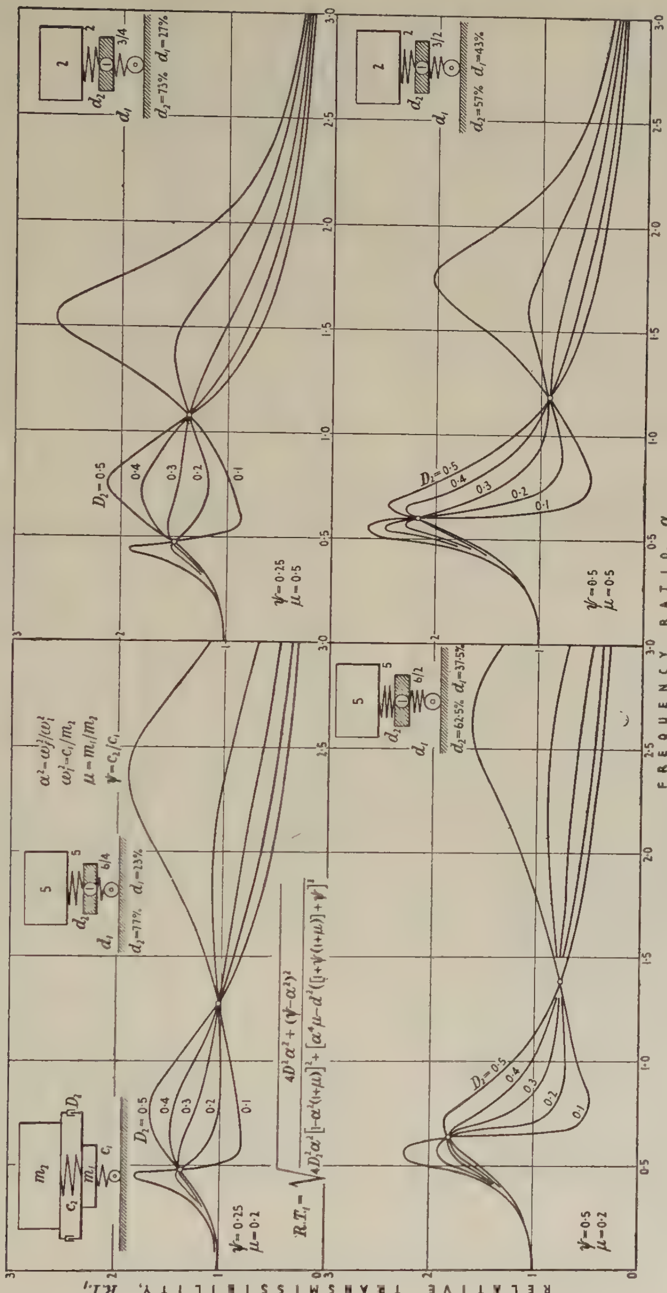

Fig. 5. — Effect of spring stiffness, mass ratio and bolster damping factors on bogie frame displacement relative to the ground.

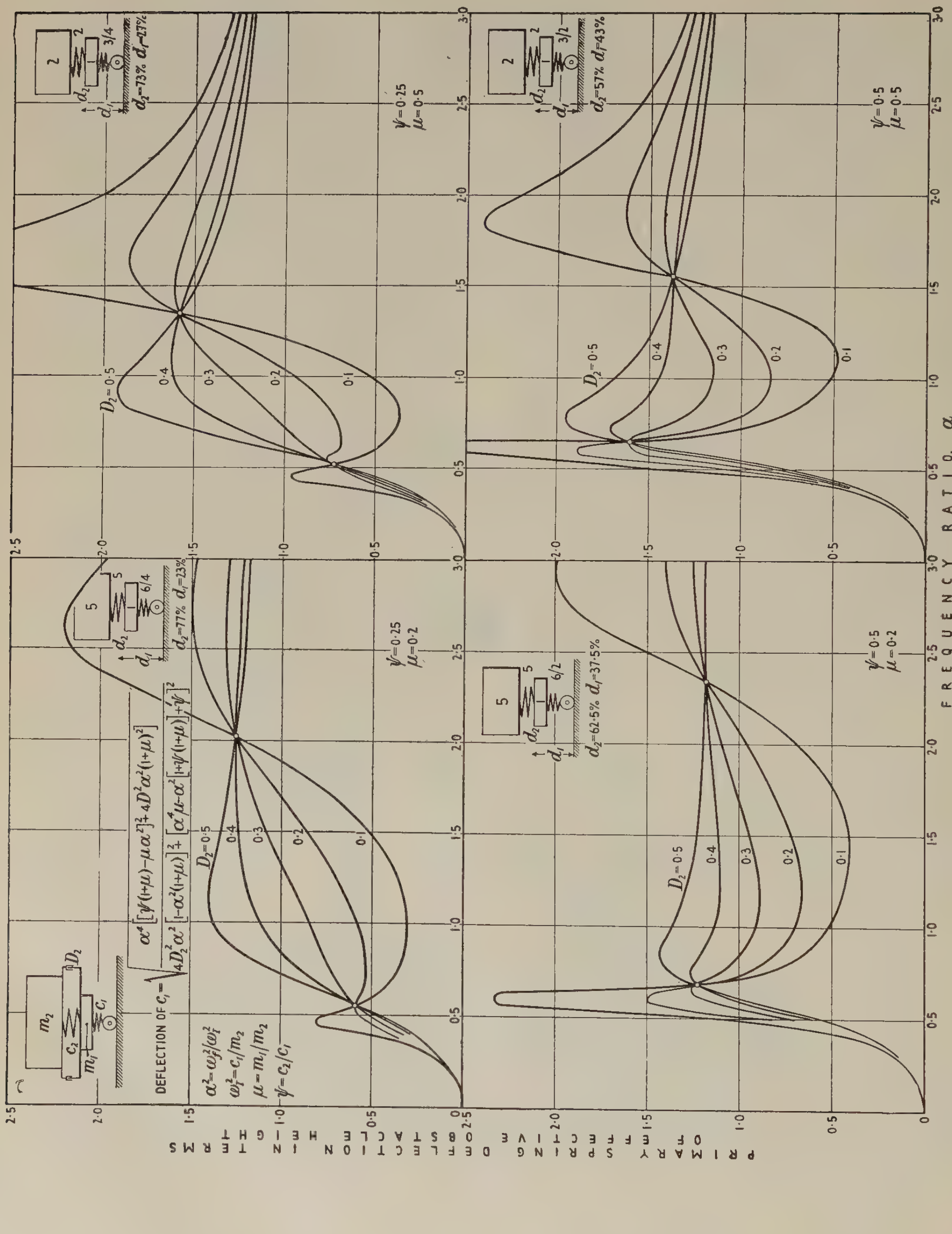

Fig. 6. — Effect of spring stiffness, mass ratio and bolster damping factors on the deflection of axlebox springs.

running over the track is likely to be reduced and the speeds and weights of trains are likely to be increased.

It also should be borne in mind that the rail stress pattern scarcely will be of a repetitive character, for the wheels are likely to pass at random fashion, while on the other hand the action of cold-rolling is likely to be of some benefit to the rails. The recital of these variables, as well as the various factors mentioned previously, suggests how difficult it will be to take account of them, yet further considerations must be devoted to the economic aspects of the matter. Thus, with freight stock, the possibilities of increasing the wheel diameters to meet P_1/D requirements are rather limited, and reducing the maximum axle-loads would be one way out. This will mean increasing the number of axles to carry a given payload, thus adversely affecting the dead weight of the train. Generally, the higher the permissible axle-load the smaller will be the number of wagons used and also the number of wagon-miles or axle-miles run. This will reduce the number of trains required and will in turn permit an increase of scheduled speeds, and with it improved rolling-stock use. In addition, the work dissipated in shunting also will be reduced as the required locomotive-hours depend mainly on the number of wagons handled. Because the tractive resistance in part is reduced with increasing axle-loads, fuel consumption also will be affected, so that, overall, undue limitation of axle-loads can result in increased operating costs.

Acknowledgments.

Acknowledgment is made to the Director of Research, British Railways, for permission to publish this article and to Mr. T.A. Eames and his staff who — with the aid of a digital computer — provided the data required to plot the curves, figures 3 to 6.

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[656 .212]

Teaching simultaneous marshalling.

Novel method of explaining, with the aid of playing-cards, hump yard shunting procedure.

by K. J. PENTINGA, Netherlands Railways.

(*The Railway Gazette*, May 22, 1959.)

If each railway wagon with its load could roll individually to its destination like a road vehicle, there would be no shunting. It seldom happens that a number of wagons loaded in a certain sequence at the same station are transported together in the same order to the same destination station and can be put at the disposal of the various consignees without alteration of the order in which they were placed in the train. In most cases wagons must be combined with other wagons at the station of departure and at intermediate stations so that their order will be changed. Shunting operations are, therefore, indispensable. Most railway companies practice their own shunting methods which they consider to be efficacious.

In this article it is explained from a purely theoretical point of view, with the aid of playing cards as in a game of patience, how the productivity of shunting in hump yards may be increased by simultaneous marshalling.

A pack of shuffled playing-cards may be sorted into correct sequence according to their suits in two ways: either, first, by sorting the cards into suits (e.g., Spades, Hearts, Diamonds and Clubs), and then by sorting the cards of each suit into their correct numerical sequence (e.g., 1-13 taking Ace = 1, Jack = 11, Queen = 12, and King = 13), or by reversing the procedure and first sorting the cards into numerical sequence and then sorting the cards of each respective value into suits. In the same way, a jumbled collection of wagons in a hump marshalling yard may be shunted by first shunting the wagons into trains and then, by the further shunting of each train, arranging the wagons in section according to the order in which they are to be detached at destinations on route or by reversing the procedure and first shunting the wagons into sections according to the order in which they are to be detached and then, by the further shunting of each section, assembling the wagons into trains.

By taking one or more packs of shuffled playing-cards containing 52 cards, it is possible to illustrate the manner in which the shunting operations of freight wagons in a hump yard can be carried out and, at the same time, to indicate the mathematical implications which will follow.

In the example below, four trains have to be made up and each train arranged in 13 sections, each train being identified by a playing-card suit (e.g., Spades, Hearts, Diamonds, and Clubs) and each section by a playing-card value. The trains have then to be assembled in the following order :

Train 1 (Spades) S1, S2, S3 . . . . . . S13
Train 2 (Hearts) H1, H2, H3 . . . . H13
Train 3 (Diamonds) D1, D2, D3 . . . . D13
Train 4 (Clubs) C1, C2, C3 . . . . . C13

Fig. 1 shows a hump marshalling yard with 13 sorting sidings and one reception siding; the wagons standing in the recep-

tion siding are to be pushed over the hump and into their respective sorting sidings. According to the normal method of shunting, the wagons are sorted first into trains (Spades, Hearts, Diamonds, and Clubs in this case) and then into sectional order thus, Spades, S1, S2, S3, ——S13; Hearts, H1, H2, H3,——H13; and so on.

In the methods outlined below, this procedure has been reversed and the wagons are first shunted into sectional order, according to their destinations and then subsequently shunted into trains. This enables trains to be shunted simultaneously, and a jumbled collection of wagons in a reception yard can be arranged to form their correct sequence by means of systematic shunting based on mathematical progressions. For this purpose use may be made of principles based on either an arithmetical series of numbers, a geometrical series of numbers, or a triangular series of numbers, to obtain a final arithmetical series of numbers, being the order in which the wagons for each particular train (Spades, Hearts, Diamonds, and Clubs) must be assembled to departure.

An illustration of each of these three methods is given below. The placing of groups of numbers within brackets such as (1, 2, 3, 4,——13) indicates that the numbers are not arranged in their correct sequence, whilst groups of numbers in arithmetical series are shown without brackets, e.g., 1, 2, 3, 4,——13. Similarly (S3, H3, D3, C3) between brackets indicate that the suits may not necessarily be arranged in that order.

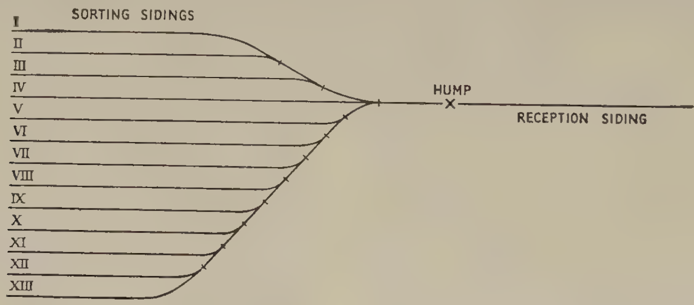


Fig. 1. — Reception siding and sorting sidings into which wagons are to be humped.

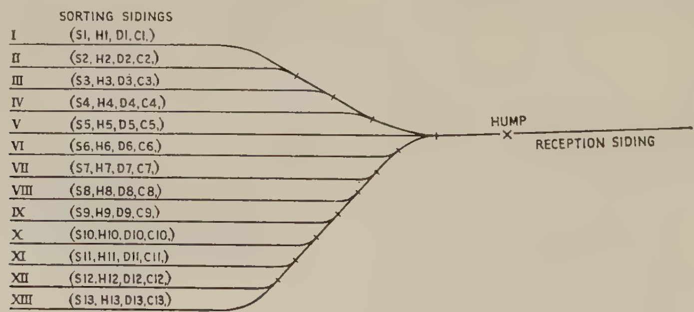


Fig. 2. — After completion of first phase.
Wagons in sectional order based on mathematical progression.

Arithmetical series of numbers.

During the first phase the wagons standing in the reception siding are passed over the hump and run into the sorting sidings according to their sections. Figure 2 shows the position on completion of the first phase, the brackets indicating that each group is not in any particular order of suits (*i.e.*, trains); for example, in the case of siding I, there are 24 possible alternatives (4 × 3 × 2 × 1) for the order in which the Aces of Spades, Hearts, Diamonds and Clubs can be arranged. The section numbers of the wagons in sidings I—XIII form an arithmetical series, viz., 1, 2, 3—13, which accounts for the name given to this method.

During the second phase the wagons in siding XIII are first collected, these are transferred to siding XII, coupled to the wagons standing in that siding and, together, they are then transferred to siding XI where they are coupled to the wagons already in that siding. This process is repeated until all the wagons have been collected. They are then again run into the reception siding on the right-hand side of the hump as shown in figure 3.

The third phase consists of pushing the wagons over the hump again, this time into sidings according to their respective trains (Spades, Hearts, Diamonds and Clubs) in the manner indicated by figure 4, the sorting sidings serving also as departure sidings (formation sidings) for this purpose.

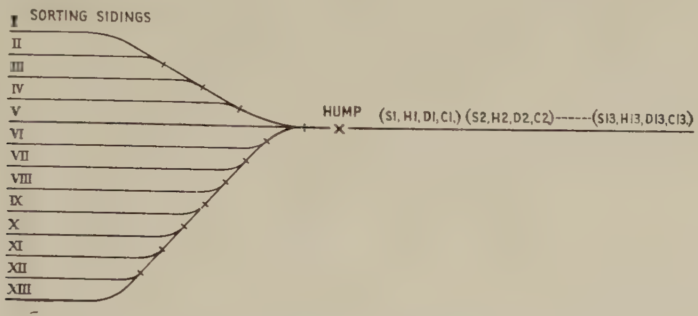


Fig. 3. — Third phase, before humping second time.
Wagons are in sectional order.

Fig. 4. — After humping second time, wagons grouped by trains in sorting sidings ready for departure.

The advantages of the arithmetical series are that the wagons need only be passed over the hump twice, and the length of each sorting siding need only be as long as the sum of the lengths of the wagons in one section.

On the other hand a separate siding is required for each destination or section and a considerable amount of time may be required during the second phase for collecting wagons from each individual siding and in transferring them to other sidings to pick up further wagons. For example, the wagons in siding XIII must

TABLE 1. — **Geometrical series of numbers.**

Siding	First phase	Second phase	Third phase	Fourth phase	Fifth phase
Sorting :					
I	(1, 3, 5, 7, 9, 11, 13, 15)	—	—	—	—
II	(2, 6, 10, 14)	+ (3, 7, 11, 15)	—	—	—
III	(4, 12)	+ (5, 13)	+ (6, 14) (7, 15)	—	—
IV	(8)	+ (9)	+ (10) (11)	+ (12) (13) (14) (15)	—
Formation :					
Spades . .	—	1	2, 3,	4, 5, 6, 7,	8, 9, — 15
Hearts . .	—	1	2, 3,	4, 5, 6, 7,	8, 9, — 15
Diamonds.	—	1	2, 3,	4, 5, 6, 7,	8, 9, — 15
Clubs. . .	—	1	2, 3,	4, 5, 6, 7,	8, 9, — 15

be transferred into each of the other 12 sidings before being finally formed into a train. Because of these disadvantages, this method is considered suitable only where each of the trains to be formed is limited to three or four sections, and to avoid the need for continually transferring wagons from siding to siding during their collection, as described in phase 2 the French National Railways have been induced to develop methods which will avoid the need for such transfers.

Table 1 illustrated stage by stage the use which can be made of a geometrical series to facilitate shunting operations. In this instance two further groups or sections have been added to each of the four trains (Spades, Hearts, Diamonds and Clubs) making 15 sections in all. Four sorting sidings are sufficient for shunting the 15 sections. Four formation sidings are also required to assemble the trains (Spades, Hearts, Diamonds and Clubs) but, if required, sorting siding I may also be used as a formation siding for one of the four trains (e.g., Spades). For simplicity the prefix letters S.H.D.C. denoting particular trains have been omitted where groups of numbers denoting the sections are shown between brackets, thus in sorting siding III during the first phase, groups 4 and 12 are shown between brackets indicating that this siding contains all the wagons which comprise the fourth and twelfth sections of each of the four trains not necessarily in any particular order.

The first phase consists in pushing the wagons in random sequence over the hump and into one of the four sorting sidings selected according to the wagons' section numbers which are so arranged that the numbers in the sorting sidings will form a geometrical series. Thus in phase one by reading the section numbers downwards from siding I to IV as shown in Table 1, sections 1, 2, 4, 8; sections 3, 6, 12; and sections 5, 10; will each form geometrical series with a common multiplier of two (e.g. $1, 2, 4, 8 = 1 \times 2^0, 1 \times 2^1, 1 \times 2^2, 1 \times 2^3$; $3, 6, 12 = 3 \times 2^0, 3 \times 2^1, 3 \times 2^2$; $5, 10 = 5 \times 2^0, 5 \times 2^1$).

During the second phase, the wagons standing in sorting siding I (section numbers 1, 3, 5, 7, 9, 11, 13 and 15) are collected and again passed over the hump, this time being run into sorting sidings II, III or IV according to their particular section numbers in the manner illustrated by Table 1 or, in the case of those wagons which form the first section of each of the

TABLE 2. — **Triangular series of numbers.**

Siding	First phase	Second phase	Third phase	Fourth phase	Fifth phase	Sixth phase
I	(1 3, 5, 8, 12)					
II	(2, 6, 9, 13)	(3)				
III	(4, 10, 14)	(5)	(6)			
IV	(7, 15)	(8)	(9)	(10)		
V	(11)	(12)	(13)	(14)	(15)	
Spades . .		1	2 3	4 5 6	7 8 9 10	11 12 13 14 15
Hearts . .		1	2 3	4 5 6	7 8 9 10	11 12 13 14 15
Diamonds.		1	2 3	4 5 6	7 8 9 10	11 12 13 14 15
Clubs. . .		1	2 3	4 5 6	7 8 9 10	11 12 13 14 15

four trains (Spades, Hearts, Diamonds, and Clubs), run directly into their respective formation sidings. The third phase consists of collecting the wagons from sorting siding II (2, 6, 10, 14) (3, 7, 11, 15); these wagons are then run over the hump and into sorting sidings III or IV, or, in the case of sections 2 and 3, directly into their formation sidings.

In the fourth phase the wagons from sorting siding III are collected and passed over the hump and into siding IV or, in the case of section 4 to 7, into the formation sidings. The fifth and final phase will then consist of running the remainder of the wagons standing in sorting siding IV, sections 8 to 15, over the hump and into the formation sidings according to their trains so that the four trains will now contain all their wagons marshalled in sequence according to their sections.

The advantages of the geometrical series are that wagons do not have to be continually transferred between sidings until all sections are collected before hump shunting can take place. This was one of the disadvantages of the arithmetical series. Whilst the number of times the wagons on the sorting siding must pass the hump increases in an arithmetical series, the number of sections simultaneously shunted into their respective train formations increases in a geometrical series. This method requires only a limited number of sorting sidings. If productivity is defined, not as the number of wagons passing over the hump in unit time, but as the number of wagons which can be shunted simultaneously into both train and section order so that no further shunting of wagons is necessary at destination stations or private sidings, then it will be seen that the geometrical series is the most efficient because it enables this to be done with the fewest movements.

The disadvantages are that the length of the sorting sidings rapidly increases with the number of sections, and the wagons are hump shunted more often than in the case of an arithmetical series. For example, when it is necessary for trains to be divided into 15 sections, the geometrical series will require no less than five hump shunts. These disadvantages have induced the French National Railways to introduce a further method for purposes of hump shunting.

Table 2 illustrates stage by stage the use which can be made of a triangular progression in order to assist shunting operations. In this example, as with the geometrical series, two further sections, 14 and 15 have been added to each of the four trains (Spades, Hearts, Diamonds and Clubs) making a total of 15 sections in respect of each train. Five sorting sidings are required for the 15 sections, with four formation sidings in which the trains are to be assembled prior to departure. Sorting siding I may, if necessary, be used also as a

formation siding for one of the four trains. For simplicity, the prefix letters S.H.D.C. denoting the particular trains have again been omitted where groups of numbers indicating sections are shown between brackets.

During the first phase, the trains are run over the hump from the reception siding and into the sorting sidings, I, II, III, IV or V, according to their section numbers, the particular siding being determined by means of a triangular series of numbers so that upon completion of the first phase, the section numbers of each group of wagons standing in the sorting sidings are arranged in a triangular series, 1, 2, 4, 7, 11. After the first phase of shunting has taken place, the second and subsequent phases follow in the manner shown by Table 2, the wagons in each phase being passed over the hump and into their appropriate sorting or formation siding.

As with a geometrical series no transferring of wagons between sidings is required before further hump shunting can take place. Whilst the number of times the wagons on the sorting siding must pass over the hump increases in an arithmetical progression, the aggregate number of sections simultaneously shunted in the train formation siding increases in a triangular series :

Number of hump shunts required .	2	3	4	5	6	Arithmetical series
Aggregate number of sections assembled in train formation	1	3	6	10	15	Triangular series

Only a limited number of sorting sidings are needed, although the number required is slightly higher than in the case of a geometrical series; for example, when 15 sections have to be marshalled, as in Table 2, one more siding is required if the triangular series is used. The wagons of sections 1, 2, 4, 7 and 11 are only shunted twice and the remaining sections three times whereas using a geometrical series more shunts per section are necessary, for example, the wagons of section 15 must be shunted five times. When trains have to be divided into seven or more sections, the maximum number of sections in any one siding is less than if a geometrical series is used.

With this method more hump shunts are necessary than in the case of either an arithmetical or a geometrical series, and sorting sidings must be of sufficient length to accommodate the wagons of more than one section, and must, therefore, be longer than when an arithmetical series is employed.

With the aid of playing-cards it is, thus possible to illustrate methods by which the productivity of shunting in hump yards can be increased by the simultaneous marshalling of wagons into both section and train order. In this way shunting operations at destination stations can be avoided.

[656 .212 .8 (42)]

Driverless platform trucks for depots.

Tests at Newton Abbot, Western Region, of electronically guided battery vehicles following energised single wire laid 1/2 in. below floor.

(*The Railway Gazette*, April 24, 1959.)

The driverless platform trucks are being tested in Newton Abbot Goods Shed, British Railways, Western Region. They haul trolleys conveying consignments, which have been discharged from wagons, to chosen points for loading into cartage vehicles for outward delivery.

The electronic guidance system is, basically, to make the truck follow a single wire laid just beneath the flooring with about ½ amp. A.C. of a specified frequency passed through it.

Driverless truck, following the wire hidden beneath the flooring, hauling trolleys along one of nine experimental tracks.

Over a year ago, E.M.I. Electronics Limited produced the driverless trolley system known as the Robotug, which the Western Region estimated had potentialities for use in association with battery-electric platform trucks. Many of the latter have stood up to use over long periods in large goods sheds in the Region.

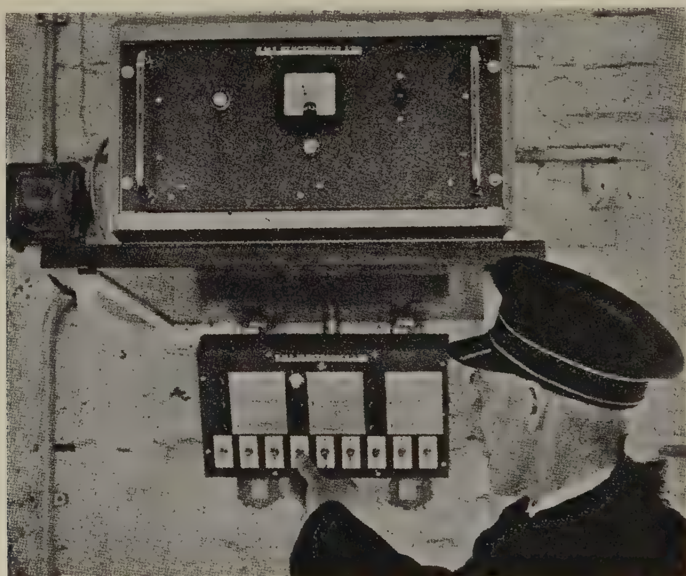
Automatic stop at obstruction.

Fitted to the front of the truck is a safety bumper, so designed that if an obstruction is met, a micro switch open circuit de-energises the interlock relay and halts the trolley.

The platform truck is the battery-electric vehicle manufactured by Scott Electric Vehicles Limited, and standard for this type of work in railway depots. It can be operated in the usual way and driven manually if required.

A durability test of hauling a 3-ton load continuously for a distance of 2-3 miles at number has been installed at Newton Abbot to afford thorough testing.

Switch panels have been provided at points in the shed. On these are push-buttons energising sections of track. The dispatcher presses the appropriate button to cause the truck to move over the selected sections to destination.



Changing the circuit to energise sections of track selected.

about 2 m.p.h. showed the battery capacity of 121 A/h to be sufficient for the work to be carried out in an 8-h shift.

Trials to be carried out over several months began on April 7. For the purpose of this experiment nine tracks have been laid 1/2 in. below the surface of the floor. It is not thought that nine tracks will be needed in most depots, but this

Packages are discharged from the railway wagon on to a train of trolleys working to and from a cartage post. These trolleys stand on the outside track of the nine circuits, away from the railway wagon, so that the inside track can be used as a running road and not impede free movement of loaded and empty trolleys to and from the cartage loading point.

[656 .2 (42)]

Inland freight.

Future trends,

by G. F. Fiennes, M.Inst.T., Great Northern Line Traffic Manager, Eastern Region, B.R. (*)

(*Modern Transport*, September 12, 1959.)

Demand for freight transport, like the habit of travel, is growing. Responsible estimates of the rate of growth are not very precise, but they agree fairly closely. The average expectation is that national production will increase by about 60 % in the next 10 or 15 years. Of that increase over one half will be translated into a demand for transport. Within that national average the demands of each industry vary widely. Coal, for instance — crystal-gazing here — will rise slightly with the expanding electrical industry, nuclear power and oil-firing notwithstanding. Oil will go up by over 80 %, steel by 60. Agriculture will remain much as it is.

The geographical demand for transport is unlikely to alter much. There are powerful opposing forces in a state of approximate balance. The social interest requires work to be brought to people rather than people to their work. When a basic industry in any area declines, the Government encourages other industries to move in. The object is a natural one, to diversify the work in each area and to spread the social risk. On the other hand the growth of the industries depending on import in bulk, the growth of the size of the unit in manufacture has stimulated development of the sea-board. On the whole this force has been contained. It has not and will not often — words carefully chosen — demand a radical alteration in the direction or form of transport.

Choice of transport.

Next, of what sort shall transport be? There is a distinction here between the national interest and the demand of the user. The national interest demands that transport shall be efficient in the service of the nation; streamlined, taut, spare, always down to its fighting weight; fighting for the best transists and lowest costs for our exports and our consumption at home. The broad principles are convenience, reliability, speed, safety and economy.

The demand of the user is for something else as well — naturally. A leading industrial expert in transport, a member of one of the great firms in this country, has written recently: « Each form of transport should be so developed and exploited that the sum total of the activities of all forms constitutes an efficient transport system produced at the lowest possible cost to the community. Co-ordination or integration is justified only if it results in greater efficiency and/or reduced overall costs than would otherwise be the case. It could not, *in any case,* be justified if there were no provision for a fair measure of competition. » The italics are mine.

National interest.

The national interest is for transport broadly equated to the national need. The

(*) Abstract of paper read before British Association for Advancement of Science, York.

individual interest is for plenty of competition, which by its nature requires a surplus which cannot be stored. There is no frozen ton-mile. Transport by its own nature is the most perishable of things. True, the lorry, the wagon, or the craft like the tree goes on until replaced. Like the fruit the service must be used as it is ready for use or it perishes. « No one is so careless of cost — other people's cost — as the user of transport. »

Having then transport on tap the user may choose his form. He may also choose within limits whether he will operate that transport himself or employ privately-owned or nationally-owned concerns. His choice depends to a great extent on the relative emphasis which he attaches to the principles of convenience, reliability, speed, safety and economy. Many industries are already geared to supply at a few hours' notice : fruit, flowers, vegetables, fish, meat, newspapers, naturally come from the source of supply through, maybe, both wholesaler and retailer to consumer in that time. More and more industries producing and distributing consumer goods have come to recognise that by gearing themselves in the same way they reduce the stocks which they hold at their premises and in the pipeline between the producers and themselves. One very large concern by taking thought released last year in this way £ 21 million for other capital use. To these industries the emphasis is on reliability and speed.

At the other extreme are the basic industries of coal, oil, iron and steel, and agriculture other than market gardening. One of their principal interests is that their processes shall not be held up by a hiatus in the arrival of their raw materials or by congestion in the dispatch of their finished products. They demand reliability, but it means something very different from reliability in, say, the fish trade. Speed is less important; a steady flow more. Economy, since transport is a larger component of the final cost of the product, is vital. Between these extremes is an infinite range of shades of demand.

Relative technical advantages.

The advantages of road transport are massive. For convenience a flexible small unit; available like the railway train at all hours of the day or night seven days in the week, but ready to move at any moment unhampered, as the train is hampered, by the organisation required to match the wagons with an engine, a crew, a brake van, and a path over the line. The unit is small; more closely matched to the unit of the country's trade than is the train of 500 tons. Lorry does not wait for lorry as wagon must wait for wagon. There are opportunities for individual service in the time of loading and unloading which the railway, running its trains to a timetable does not offer.

In regularity the advantage of the smaller unit direct from door-to-door under the personal control of its own driver, predominates over the railway's practice of transhipment from road to rail at the outward rail terminal, of combination with other wagons to form a train, once, twice, or three times on the journey and of transhipment from rail to road at the inward rail terminal — on rail all this controlled by remote control of a series of individuals, none of whom has a direct interest in the journey as a whole.

Speed.

In speed an average of 20 m.p.h. allows overnight transists up to, say, 250 miles. There are few large centres of production or consumption in the country which are farther than that distance apart. The speed of the lorry, which by no means matches that of the railway train, is firstly good enough and secondly is a true overall door-to-door speed, whereas the speed of the train is often of no account by reason of the delays inherent in the road-rail transfer and in marshalling yards.

In safety the personal supervision of the driver gives road an advantage. The door-to-door service with no transhipment to cause damage or loss, or shunting to cause

damage. On the other side of the account is, firstly, the road accidents costing £ 175 million a year, and, secondly, the roughness of travel by road compared with rail. Some work on this subject done in Germany appeared in *Neue Verpackung* in June, 1958. It showed that the stresses of acceleration and deceleration on a road journey are as high as 6.0 g transversely, 0.6 g longitudinally and 3.0 g vertically, compared with 0.2, 0 and 0.2 g on rail. Even in shunting on rail stresses above 1.5 g were most exceptional. These results are probably valid for this country, except for the stresses in shunting. In Britain it is common ground that road journeys cause less damage than rail and that such stresses are not significant. But rail journeys can be made less arduous than road.

Rail advantages.

This brings us to the advantage of rail. In convenience the service, nation-wide, ranks high. Next, the railway wagon will stand silently and comparatively cheaply awaiting the senders' or consignees' pleasure. The length of the queue matters less on rail than on road, whether viewed nationally or individually. Thirdly, most of the important industries are expensively geared to rail for inward and outward traffic with private sidings, mechanical loading and unloading. Some 95 % of railway tonnage is loaded and 74 % unloaded in private sidings. Much of the rest — domestic coal, for instance — is unloaded in railway yards where the merchants have space for storage.

In regularity the only point to be made for rail at the moment is that express freight trains on the move run reasonably punctually. There is a timetable which demands precision. In winter some 60 % are within 30 min of time; in summer some 80 %. The proportion of express freight to the whole is rather more than one-third. Traffic, therefore, which travels on express trains and neither needs to transfer from road to rail or is especially treated as it does so, nor passes through marshalling yards, has a reliable transit on rail. For the speed of movement rail is far superior. Fish and meat trains at average speeds of over 45 miles an hour and express freights at 35 and upwards have no parallel on road.

Advances in prospect.

Air transport development is likely to be along lines which will avoid the delays and dangers of transhipment at airports. This development can take the form either of the use of helicopters or other vertical take-off aircraft which will use the senders' and consignees' premises, or alternatively of conventional aircraft capable of absorbing vehicles or containers in its belly. Such transport by air will have much the same convenience, reliability and safety as the road unit. In speed it will be superior which will not matter very greatly since except over the longer distances road can, and rail will do everything which is necessary overnight. In cost it will be high. It will be used in two ways; the first to cream some highly profitable traffics, largely from road; secondly, and more sensibly, to carry over long distances traffics which are highly perishable.

Apart from road, rail and air, there are specialised forms of transport for certain products. Transmission lines for electricity and pipelines for gas and oil have special attractions.

Road pros and cons.

For road transport there is a network of motorways planned along the principal arteries or the country — 1 500 miles of them. There is a great programme of improvements to the existing trunk roads. The vehicle itself can develop little in capacity owing to the physical limitations of the track, especially of the bridges. It is unlikely to develop greatly in speed. There has been a signifiant reluctance on the part of the road industry to press on with the change from 20 m.p.h. to 30 recently permitted. There will be a marked trend towards articulation, separating the motive unit from the carrying.

On the other hand the forces moving against greater efficiency in road transport are considerable. The increase in the number of vehicles on the road may be more than seven million in the next 12 years. If the motorways speed movement through the country, the congested approaches to the terminals in the towns may offset that advantage. The increase in utilisation of the motive unit by articulation works for greater efficiency. Against efficiency works the increasing complexity and cost of the unit itself, the higher crew cost stemming from tighter organisation of union membership and — be it said softly — wider observance of the law. In short, opinion is that the efficiency of road transport will not surpass by much its present high level.

The railway revolution.

The picture of the railways emerging from the age of the Stephensons is very different. Here the technical advances are revolutionary. The advances are under four principal heads: traction; design of rolling stock; marshalling yards; and terminals. There are indeed other things — stronger track; better signalling; automatic warning control to suit the higher speeds — but they are not fundamental to the end product, which is a revolution in service.

Road-rail transfer is, in the author's view, the nub of the matter, the key to the railways' continued existence. Economically they cannot continue to exist on the bulk traffics alone. They must secure a higher share of the consumer goods which require transport, not siding-to-siding, but door-to-door. Railways have been shown to be faster and safer and sufficiently reliable when on the move. They throw away those advantages at terminals and in marshalling yards. There is no better way to cope with either difficulty than to avoid it.

Container and amphibian.

The design of a container is partly a problem in design to suit individual trades: to tip for some bulk traffics; to discharge by compressed air for others; to refrigerate; to carry greater weights. It is partly a problem how to transfer it between road and rail. The road-rail vehicle may be either a piggy-back one which climbs on to a railway chassis, or a true amphibian which runs with the same chassis on road or rail. In America the piggyback is in wide use. Here, with a smaller loading-gauge, the design is difficult. The development of the amphibian is more likely. A prototype is under test.

The upshot of these two things alone or in combination will be the ability of the railways to transfer full loads between road and rail in a negligible time at a negligible cost and with no risk of damage. To safety in shunting, of which more under marshalling yards, the contribution of the designer of rolling stock is an improved buffer and coupler, the effect of which will be simply — and no more need be said — to remove the risk of damage from shunting.

Yards.

Next, marshalling yards. The unit of the country's trade is less than a train load. The unit of a railway's operation is a train. Hence the device of marshalling yards for combining and dispersing the smaller units into and out of the larger. A necessary evil up to a point and that point is now several places away from where it was. Our forefathers could put no more than a thousand wagons a day into a marshalling yard of some 17 sidings. That was the reasonable limit which an engine could do shunting on the flat. As traffic grew to the point where there were 1 500 and then 5 000 wagons a day passing through a junction, there was nothing they could do but add to the one yard — and each time they did so they increased the number of wagons transferred between each of the yards, so they required still more yards.

At one such concentration with which the author was concerned a little while ago, a little less than 5 000 wagons a day entered and left the area; we shunted over 12 000,

each on average 2 1/2 times. Now techniques have advanced to the point where we can shunt over 5 000 wagons a day in one yard. In the case quoted, 15 yards were combined in one main throughput yard and two storage yards. Through electronically controlled rail brakes damage in marshalling yards will become a thing of the past.

Terminals.

On terminals there are three main streams of thought. Firstly, the basic industries whose transport costs are of so great a proportion of their selling price will continue allied more firmly than ever to rail. Their need will continue to be receipt of raw materials in and dispatch of finished products from their own siding. Where their customer also has a siding, well and good. Where their customer has not, the new techniques of road-rail transfer will accelerate and simplify the transit. Secondly, by virtue of these new vehicles the railways will no longer be tied to particular terminals. Any tarmac alongside the track will do.

Thirdly, for small consignments which must be sorted the concentration into terminals 20 or 30 miles apart will have the effects, firstly, of making mechanisation worth while with its benefits of speed and low costs; secondly, of making train loads from the terminal with benefits in speed by avoiding marshalling yards; and, thirdly, of reducing damage in handling by the use of conveyors.

To control loading, shunting and movement of trains by push-button is no idle dream — the railways ultimately, as pie in the sky, can look to automation.

The picture of railways reduced in number, but convenient, reliable, fast, safe and cheap, may seem to the reader as special pleading by a railway man. Of course it is; but let the author say two things. We tend in this country to be so objective, to be so fair to others, that we reduce everything to the average level of dullness of ditchwater. Secondly, the author has set down what the protagonists of air, water and road have said for themselves. If there is a great deal more to be said for railways, then it is because the technical advances in railways over the next fifteen years will be far greater than in other forms of transport.

[**656** .225 (73)]

Rubber « pillows » cut damage.

(*Railway Age*, March 30, 1959.)

Inflatable pneumatic dunnage is here to stay. A growing number of shippers now prefer it to wood and steel blocking for certain carload shipments.

Its ability to reduce damage to lading has been well proved. What's more, shippers and carriers alike have found that its use slashes deeply into the time, and therefore the cost, involved in loading a car.

Variations on the theme are cropping up, within the AAR and elsewhere. A new producer entered the market last year. One solution to the problem of return may be in sight. Meanwhile, the focus gets sharper on the big controversy : can — and should — railroads themselves supply the dunnage bags?

In Chicago a few weeks ago, inflatable pneumatic dunnage got a healthy push toward widespread acceptance by shippers and railroads alike. The occasion was a seminar conducted by the A.A.R's Freight Loss and Damage Prevention Section. Be-

hind it was a significant fact — the forthcoming publication by the section of a general information series on inflatable dunnage.

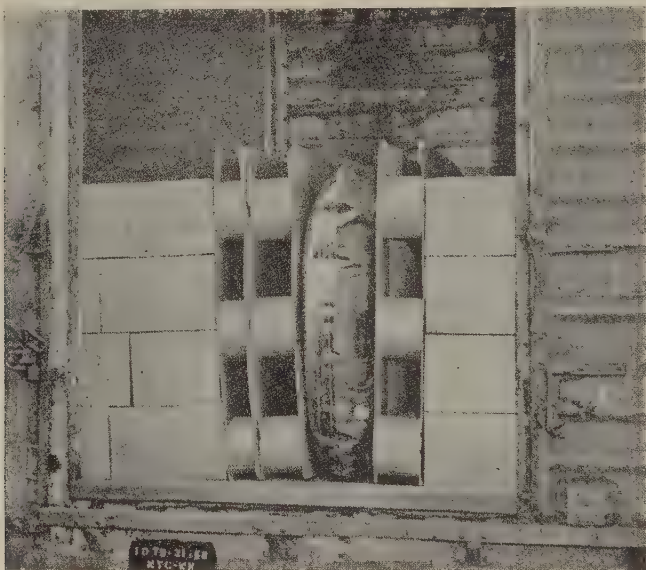
Up for discussion were the various types of heavy-duty rubber « pillows » which provide, through relatively low air pressures, both containment of a load and the resiliency to absorb shock. Proponents feel that inflatable dunnage can, in most applications, do a better job than fixed bracing. They argue that wood and steel dunnage can't be constructed to take up the slack created by compression or movement of a load after a car is started on its way.

Out of the seminar came this consensus: Almost always, wherever it's being used, pneumatic dunnage is successfully reducing both lading damage and loading costs. Reports of success were numerous. Reports of failures were few, and some users who encountered trouble were reluctant to blame the pneumatic dunnage altogether. In sum, pneumatic dunnage seems to have proved itself from the point of design and application.

But still to be hashed out are some big problems — bigger ones, most likely, than that of making the air-filled pillows work:

Who's to buy them? — Enthusiastic as many shippers are, they contend it's the railroads' duty to provide pneumatic dunnage as they provide other types of specialized loading gear. And as enthusiastic as many railroads are, most of them are standing by their position, as written into tariffs, that shippers must block and brace their loads no matter what kind of dunnage is used.

How to return them? — Getting the deflated bags back to origin after a car is unloaded bothers many users. Railroad thinking is, in some quarters, that return may be more trouble than the dunnage is



Expendable bulkhead helps dunnage fill void, spreads out pressure so it's uniform across the face of the load. Made of cardboard, its cost is low. It can be discarded after a few uses.

worth. One officer commented privately that one of his men spends most of his time chasing around after another road's dunnage bags. Others think that only those who haven't tried the dunnage regard return as a problem.

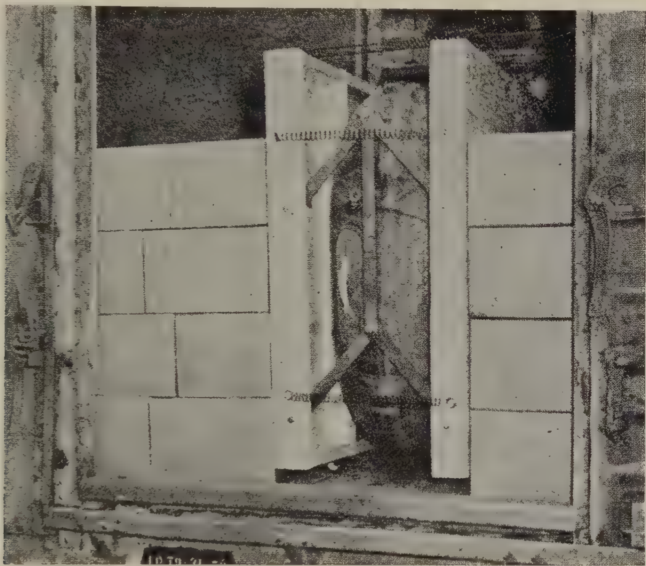
Nonetheless, present use of pneumatic dunnage is well beyond the experimental stage. Producers report that some 15 000 units are in service. One supplier's sales volume jumped 100 % in 1958. Another figures it will double its sales within months. And a new manufacturer, Firestone Industrial Products Co., entered the field last year. Through this subsidiary, Firestone Tire & Rubber Co. is following up on the pioneering done by U.S. Rubber and the later exploration by New York Rubber, Goodyear and Goodrich.

Inflatable dunnage is simple and effective. In any of its numerous available shapes and sizes, it resembles an oversized, flattened inflatable pillow. Actually, that's just about what it is. Most models consist of a butyl rubber bladder encased in a tough skin of neoprene-coated nylon fabric.

How car is loaded.

In use, inflatable dunnage is far simpler than time-honored methods of bracing a load. The proper assortment of dunnage bags is slipped into whatever void remains after a car is loaded. Pumped up to a pressure ranging perhaps only as high as 5 psi, they hold the cargo firmly in place through the shocks to which it will be submitted in transit.

On delivery, the bags are deflated, removed and sent back home in whatever way is found best — rail L.C.L., truck L.T.L. or Railway Express being among the usual methods. The bags generally are shipped in a carton or canvas container which goes along with the loaded car. Meantime, dock workers can be unloading



Dunnage « Sandwich » is A.A.R.-developed device which does same job, yet could be classified as special equipment. A commercial version is offered by Standard Railway Equipment Manufacturing Co.

the car without hacking their way through wood and steel dunnage.

Ideal as this method may sound, its use is not universal. And there are drawbacks. Rail and shipper representatives at the Chicago meeting last month hit the highlights.

Among railroads themselves, Norfolk & Western has been a leader in the use of pneumatic dunnage. Its tariffs permit it, under certain conditions, to supply the dunnage in cars which the road itself loads. N. & W. has conducted upwards of 2 000 tests in the past year. Three hundred dunnage bags have been in use.

Partial test results show up like this :

— Ten cars containing cases of cans of evaporated milk were shipped out of Abingdon, Va., with pneumatic dunnage and impact recorders. Representative carloads sustained impacts of up to 10 m.p.h. Yet, of 13 735 cases shipped, only one was damaged. N. & W. couldn't fully determine the cause of the damage to that one case due to its position in an otherwise undisturbed load.

— In another series of tests on imported canned goods, 94 328 cases were shipped, representing 80 carloads. Some 259 cases were damaged, for a performance record of 2.7 cases per 1 000 shipped. Recognizing that the figures aren't strictly comparable, N. & W. still feels this is highly superior to the national average of some 40 cases damaged per carload.

— Another report : some 183 cars of canned goods were billed from Norfolk to Detroit, Toledo, Cincinnati, Cleveland and Grand Rapids. Of the total, 91 were delivered with no boxes requiring recoopering or in bad order. An average of 18 boxes per car, or 3 306 in all, required recoopering. Of these, 2 139 were delivered in bad order, an average of 11.7 per car.

Its experience with pneumatic dunnage prompted N. & W. to step out into unexplored territory. The road sought to expand its tariff authority so it could supply inflatable dunnage on a test basis for a year. But other roads in the territory turned the idea down.

It's been talked of elsewhere, however, and is expected to be discussed again as shipper acceptance of pneumatic dunnage grows. Some shippers say they fail to see the difference between inflatable dunnage and other special loading devices, even though the dunnage bags are not permanently secured to the car.

Costs are low.

Meantime, some shippers who have seen the dunnage with which N. & W. and other roads are experimenting, have gone out and bought some themselves.

Baltimore & Ohio also has experimented with the inflatable dunnage.

The road has kept close tabs on the economics of the product during its first experiences, especially the cost of returning the bags and the effect of that cost on the cost of dunnage per ton.

B. & O. reported at the A.A.R. meeting that it had bought 10 bags, each costing $ 69.50. It estimates their useful life at three years. (Some reports indicate they may last longer.) Average round-trip cycle time has been running at 23 days. Therefore, over the useful life, B. & O. figures it will get 47.6 trips out of each bag. Thus, the dunnage cost per bag per time used would be $ 1.46.

The road also has found that an average of 1.91 bags is used per car, yielding a total bag cost per car shipped of $ 2.79. Add 51 cents for a carton for return, and $ 4.41 for return freight charges, and the total dunnage cost per car shipped is, by B.& O's pilot study, $ 7.71.

Direct labor cost runs to $ 2.45 per car, yielding a total dunnage and labor cost of $ 10.16. Test shipments averaged 26.8 tons to a car. The total cost of inflatable dunnage per ton, then, amounts to 38 cents. The labor cost, by the way, includes an estimated half man-hour to handle and install the dunnage in a car.

Aonther B. & O. study, based again on limited experience, compares the cost of various blocking techniques. These figures stand out : inflatable dunnage costs 38 cents per ton based on loads of 53 572 lb. Block-

ing a load in a specially equipped car costs 28 cents per ton on a load of 55 000 lb.; 38 cents on a load of 40 000 lb. But in a regular car, conventional blocking costs from 55 cents to $ 2.53 per ton (for mixed or stop-over loads), depending on size of load and type of blocking used.

Leasing studied.

Whatever the cost may be, one way is being paved to take much of the problem of return out of the hands of both shipper and carrier. Here and there, agencies are cropping up which intend to lease pneumatic dunnage to shippers and to handle supply, return and maintenance for a flat charge. Such operations depend on volume, of course.

But already Loading Service Co. of Medford, Ore., is establishing agencies in New York and San Francisco, sees Chicago as its next target, and is planning a fourth depot in the Southeast. A representative price for the package : $ 15 for two 4-ft. by 6-ft. bags per car shipped. That's less than many shippers must spend to block a car by conventional means — and hope it holds together.

A similar service is being planned by Rowland W. Dobbins, a freight traffic specialist in Minneapolis.

One of the drawbacks to pneumatic dunnage brought out at the seminar was its tendency, when inflated to relatively high pressures, to become spherical. The bags then exert more pressure at the center of the load than at the edges and can, if care isn't taken, crush boxes or crates. Or they might work their way toward the top of the load or push the top rows of cases out of position.

The problem can be overcome, sometimes, by inserting a sheet of corrugated board, Masonite or plywood between the face of the load and the dunnage bags. Use of the proper number and size bags helps, too. A more elaborate, but promising, answer could lie in two types of dunnage bulkheads developed by the A.A.R.

Participants at the meeting saw both expendable and permanent bulkheads as developed in the A.A.R. lab. The expendable bulkhead is made of corrugated board and compensates for the shape of the dunnage by permitting it to push into the interior of the bulkhead. The surface against the load is flat. Cost of the bulkhead is low enough so it can be discarded after a few uses.

More permanent in nature is the other A.A.R.-developed device. In fact, it could be offered as special equipment and kept regularly assigned to certain cars. It amounts to a plywoodfaced « sandwich », the sides of which remain flat and parallel to the edge of the void as the bag is inflated. Springs return the « sandwich » to its narrowest dimension when the bag is deflated, so it can be wheeled out of the car to facilitate unloading.

The A.A.R. hopes to begin test shipments with its variations on the pneumatic dunnage theme shortly. Meantime, Standard Railway Equipment Manufacturing Co. has announced that it's ready to build out of either aluminum or steel a pressure regulator frame patterned closely after the A.A.R. « sandwich ». Measuring 6 ft. by 8 ft., the frame would expand from 8 in. closed to 24 in. fully opened. Total weight in 1/8 in. aluminum, with bag, would be 285 lb.

Also coming soon is a 50-ft general merchandise box car equipped with the « pressure bulkheads » installed some months ago in an insulated box car by Homer H. Dasey, an engineer, in conjunction with Westinghouse Air Brake, U.S. Rubber, and J. H. Overpeck Co., in Pittsburgh.

The bulkheads are dunnage bags hung permanently in the car, movable as to position, and fed from an air reservoir so they can build up pressure to take up whetever additional void is formed by load compression after the car is under way.

[656 .25 (73)]

Recent track circuit developments,

by Crawford E. STAPLES.

(*Railway Signaling and Communications*, September 1959.)

The following is an abstract of a paper presented by Mr. Staples at the Cincinnati Sectional Meeting of the Signal Section, A.A.R. Mr. Staples is Section Engineer, System Analysis, Union Switch & Signal — Division of Westinghouse Air Brake Company.

Phase selective A.C. coded track circuits with D.C. track relays provide improved defective insulated joint protection and a high degree of shunting sensitivity, broken rail and foreign current detection.

In the coded detector arrangement, where it is not necessary to distinguish between different code frequencies, the track can be a retained neutral relay. It can detect code without requiring a code following relay. Twenty-one of these track circuits have been in service for 17 months in two interlockings at New Haven.

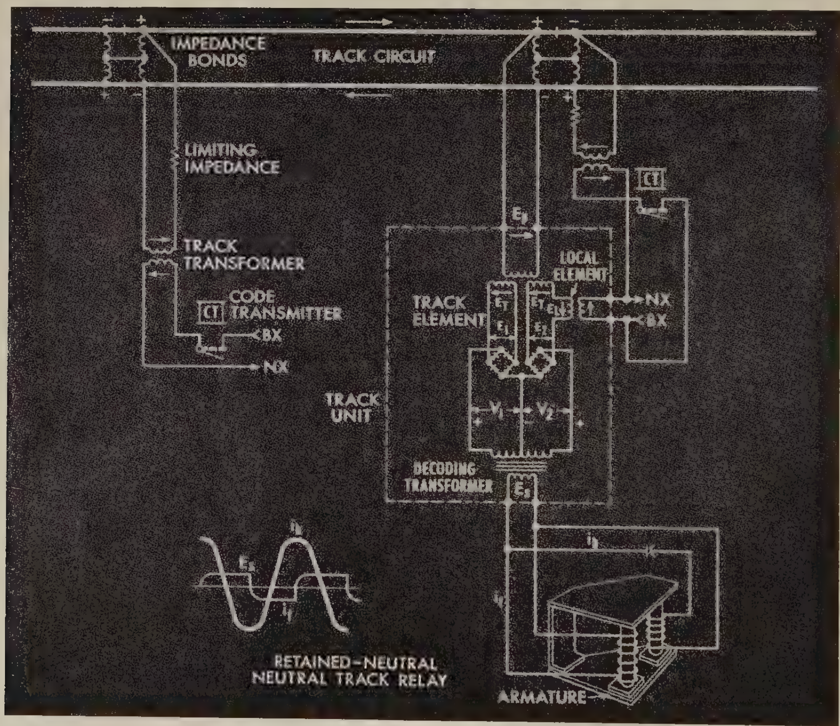


Fig. 1. — The circuit diagram for the phase selective A.C. coded track circuit. Voltages V_1 and V_2 may be utilized in other arrangements.

The new phase selective A.C. coded track

circuits were developed to replace centrifugal frequency relay track circuits in A.C. electrified territory. Use of D.C. relays reduces the maintenance required by the A.C. relay. They require considerably less equipment than the single element A.C. coded track circuits with lockout now extensively used in A.C. electrified territory.

The new circuits have a flexibility which permits their use in most of the coded wayside and cab signaling systems now in use. Installations of A.C. single element coded track circuits now in service may be readily converted to phase selective two element circuits with the substitution of new track units and modification of the code following track relays; this feature is of particular value where it is difficult to maintain insulated joints, even in non-electrified territory.

The design of the unit elements and the adjustment of the limiting impedance, a resistor or reactor, is such that during the *on* period of code, the track and local secondaries buck, so that output voltage E_1 exceeds output voltage E_2 (see fig. 1). However, during the *off* period, the track element transformer voltage, E_t, is negligible, so that output voltage E_2 exceeds output voltage E_1. Thus, when the feed end of the track circuit is coded, the differential in the output voltage alternates at the code rate.

However, if an insulated joint becomes defective with staggered polarities, E_p and E_t will be reversed, and the track and local element secondaries add, so that output voltage E_2 exceeds output voltage E_1. Thus, coding from the adjacent track circuit over defective insulated joints does not change the direction of the differential between the outputs.

Summarizing, during the off period of coding, or when an insulated joint is defective, E_1 is less than E_2. During the on period, E_1 will be greater than E_2.

The two A.C. output voltages are converted to D.C. output voltages V_1 and V_2 by full wave rectifiers. Thus, under normal unoccupied conditions, voltage V_1 will be alternately greater than or less than voltage V_2, alternating at the code frequency. In case of a shunt or feedover from the adjacent circuit, voltage V_2 always exceeds voltage V_1. In case any part of the unit shorts or opens, alternation of the voltage ceases. Even a high degree of A.C. frequency selectivity is obtained with this arrangement, because the bucking required to alternate the output voltage difference is effective only if the frequencies applied to the local and track elements are within a few cycles.

The D.C. output voltages V_1 and V_2 may be fed directly into a doublecoil magnetic stick code following relay, such as the Style C.D.P. This arrangement can be used for different code frequencies, using standard decoding. It is possible to use steady energy for block indication or traffic locking, so that any of the basic coded track circuit control systems may be used. The code following relay follows the code transmitter only when the entire circuit is intact. Operable track circuit lengths are the same as for single element coded A.C. track circuits.

Where only track circuit detection is required and where the track circuits are fairly short, as in interlockings, the code following relay can be eliminated by feeding the D.C. output voltages V_1 and V_2 into a decoding transformer. This transformer has a core of rectangular hysteresis loop material, so that alternating output voltage E_g is obtained only when the input winding is being pole changed, which occurs only when the track circuit is properly coded (see box for more details on this transformer).

Output voltage E_g, under normal conditions, is nearly a square wave voltage alternating at the code frequency. This is fed directly into the front coil and through a capacitor into the back coil of a retained-neutral relay, such as the Style D.N.-26 or P.N.-67R. This relay has three cores, on two of which are placed coils. The current in the front coil i_f and the flux through the front core follow the voltage E_g, but the current through the back coil i_b and the flux through the back core lead the voltage E_g because of the series capacitor, so that the flux reverses in one

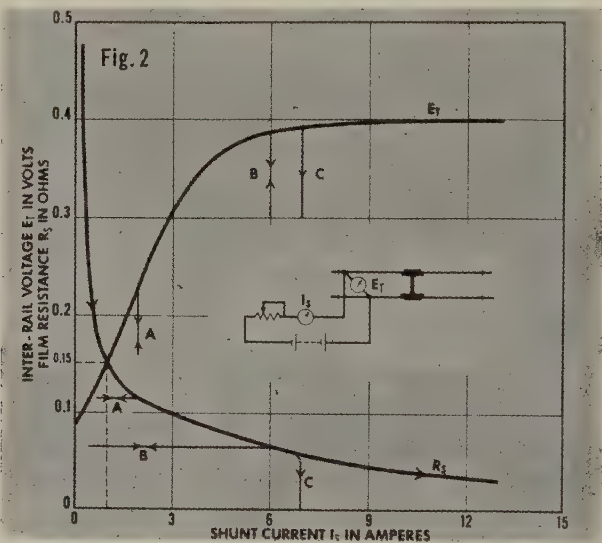
core while the flux in the other core is a maximum. The third core offers a return path for the unbalanced flux. In effect, the field rotates through the three cores, holding the armature in its closed position.

This combination is designed to operate on one code frequency, although it can reset on other code frequencies where cab signaling is involved. It has very high shunting sensitivity, having an unusually high release to pick-up ratio, quick release and slow pick-up. Generally a slow pick-up repeater relay will be required to take care of possible bobbing during the first two cycles of code until the phasing of the current in the two coils gets in step. This repeater relay also greatly improves defective insulated joint detection and momentary loss of shunt protection.

The track unit, including the decoding transformer, is housed in a Style W.-20 transformer case. A smaller unit can be used with the code-following relay arrangement.

Hi-Shunt track circuits.

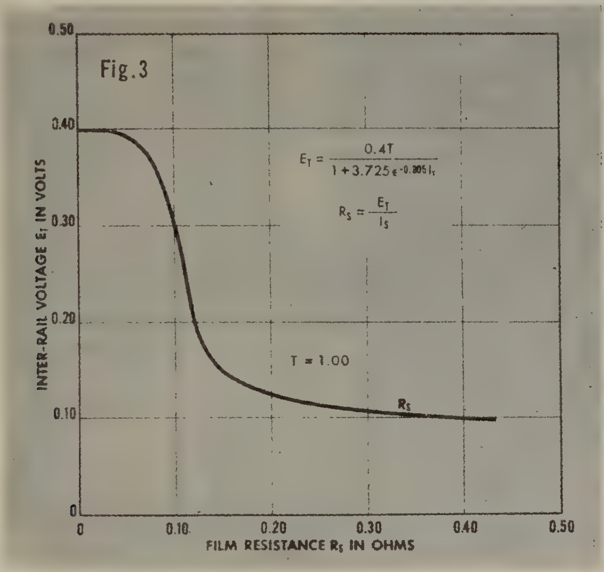
The Hi-Shunt track circuit has been developed to overcome the problems presented by film coated short track circuits in automatic classification yards. Over a period of years we have made many observations on rail and wheel films. The curves in figure 2 are an average of a number of tests, with one or two axles standing in the circuit, the car spotted at a high resistance point. As the current is increased, the film resistance drops. In some cases the curve is reversible : decreasing current increases resistance. More commonly, when the current is reduced, the film resistance stays the same, as at A or B, but if the current is further increased, the resistance is reduced still more. In some cases, as at C, the film suddenly punctures, and resistance becomes negligible. The corresponding interrail voltage is shown on this curve.

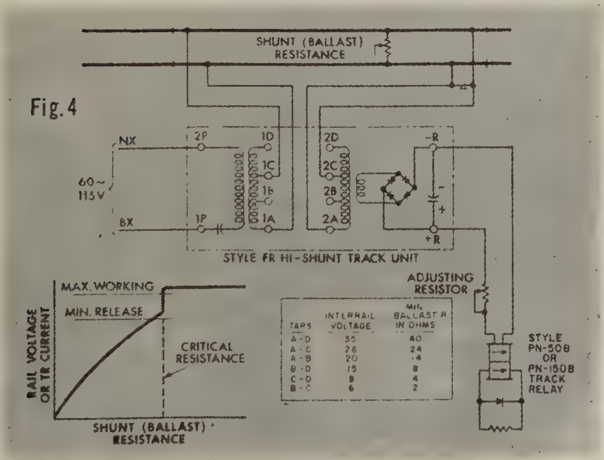


The curve in figure 3 shows the relationship between the interrail voltage and the film resistance, and the characteristic formula. The values are for a film of unit thickness, such as may be encountered on main lines with dirty wheels. Since the film resistance is a function of the current through it, thicker films increase both the interrail voltage required to pass a given current, and the film resistance, proportionally to the thickness. Thus, the shape

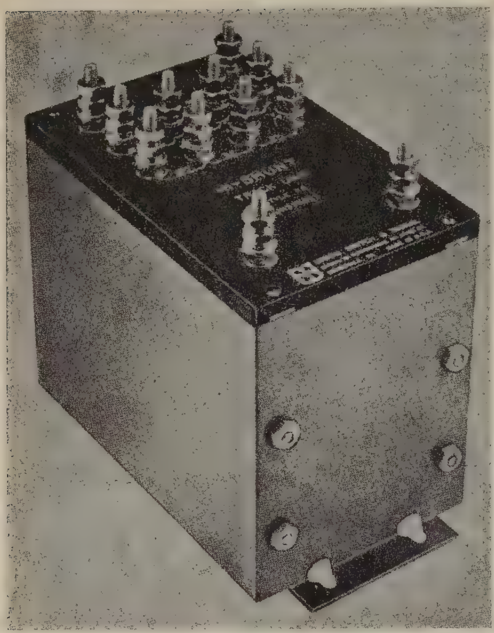
of the curve does not change with a change in film thickness.

The Style F.R. Hi-Shunt track circuit, figure 4, makes use of a series ferro-resonant circuit, consisting of a capacitor, non-linear reactor, and resistive load. In this case, the track circuit load is connected across a secondary winding of the non-linear reactor. As the shunt resistance increases, the interrail voltage increases up to a critical value, at which point the reactor suddenly passes into saturation, and the interrail voltage suddenly rises. Since the reactor is saturated, the interrail voltage





TAPS	INTERRAIL VOLTAGE	MIN. BALLAST R IN OHMS
A-D	35	40
A-C	26	24
A-B	20	14
B-D	15	8
C-D	9	4
B-C	6	2



Union Switch and Signal's style FR Hi-Shunt track unit.

will not rise appreciably at higher ballast resistances. Consequently, the track relay current and pick-up and shunt times remain relatively constant.

In applying the Style F.R. Hi-Shunt track unit to a track circuit, taps are selected which provide for a critical resistance slightly below the minimum ballast resistance. We have used taps A.-C. at West Conway without any low ballast trouble. The same taps are used on the track relay rectifier transformer. In case lower ballast resistance is encountered, both sets of taps are changed in accordance with the table.

Now let us see how you can improve your shunting performance on conventional D.C. track circuits where you may be having trouble due to rail or wheel film.

In figure 2 you saw a set of curves which showed the relationship between axle current, interrail voltage and film resistance. These curves represented averages values for dirty spots on wheels on main line track, taken from many field tests. For instance, with 1-A axle current, the interrail voltage averaged 0.15 V, indicating a film resistance of 0.15 ohm. Higher interrail voltages lowered the film resistance; lower interrail voltages raised the film resistance. These average values we called unit thickness.

Obviously, the normal film must be much less, or 0.06 ohm shunting sensitivity would have no meaning. However, from shunting performance we know that sometimes the film is much greater. It is desirable to make the interrail voltages penetrate the film encountered, so far as possible, covering up the momentary losses of shunt with a slow pick-up repeater relay.

The curves in figure 5 show the effect of the battery limiting resistance adjustment on the maximum rail or wheel film thickness which can be penetrated sufficiently to shunt the track relay, the scale being in previously defined units of thickness.

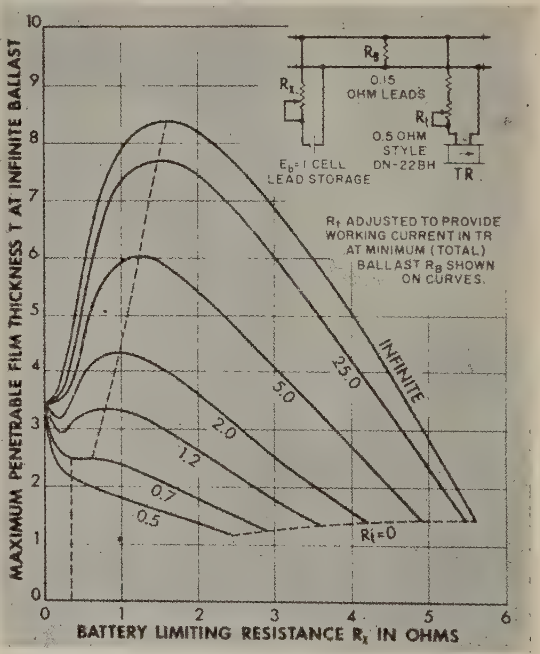


Fig. 5. — Dotted line indicates optimum battery limiting resistance, R .

These curves are for a typical track circuit using a single lead storage cell with an 0.5-ohm Style D.N.-22B.H. relay, with a series resistor R_t adjusted to provide working current in the track relay at minimum total ballast resistance R_b. As battery limiting resistance R_x is reduced, resistance R_t must be increased. The film thickness which can be penetrated is determined at infinite ballast; it will be greater at lower ballast resistance.

You will note that if the adjustment is made entirely at the battery end so that R_t is zero, the penetrable film is only a little over unit thickness. Decreasing R_x and increasing R_t improves the film shunting characteristic considerably. These curves also show that the higher the minimum ballast, the better the shunting.

If te minimum total ballast resistance is 0.7 ohm or less, it is best to make the battery limiting resistance as low as possible. This would correspond to a track circuit about 4 000 ft. in length with a minimum ballast resistance of about 3 ohms per thousand feet.

For shorter or higher ballast resistance track circuits, there is an optimum resistance setting, as shown by the dotted line. The 5-ohm ballast figure might represent a typical « O.S. » track circuit, with 600 ft. of track at 3 ohms per thousand feet. For this circuit, the best value for R_x would be about 1.25 ohms, and then R_t would be about 3.5 ohms.

There are other advantages in using an adjustable resistor in series with the relay. It is easier to set the relay current properly, and the shunting is made faster. The quicker shunting also improves shunting performance and reduces joint-hopping problems, which are a factor with single unit self-propelled cars.

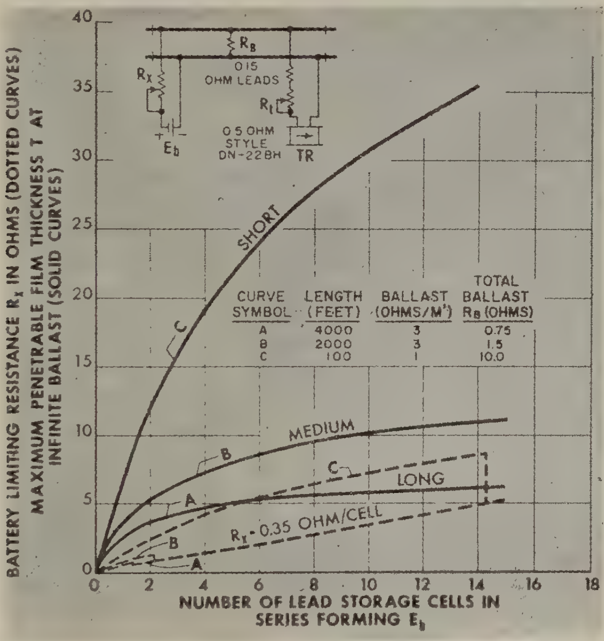


Fig. 6. — These curves show the effect of increasing the cells in series in the track battery.

Higher resistance track relays will shunt with a somewhat thicker film, but the relative series resistance is lower, so that

shunting time is longer, and shunting performance is not necessarily improved. Conventional relays, such as the Style D.N.-11, will shunt through only two-thirds the film that the Style D.N.-22B.H. will shunt.

Film shunting can be improved by raising the battery voltage. For instance, if you use two lead cells in series, double R_x and double the minimum ballast R_b, the penetrable film thickness is also doubled. Of course, in a specific track circuit you cannot readily change the minimum ballast, so the film thickness is not quite doubled.

The actual effect of increasing the number of cells in series in the track battery is shown on the curves in figure 6. They represent three typical track circuit, a long circuit A, a medium length circuit B, and a short track circuit C.

The break points in the dotted curves indicate where it becomes desirable to reduce the battery limiting resistance to a minimum, instead of using a calculated value. These points occur where the number of cells is about 1 1/2 times the minimum total ballast resistance.

In general, with the 0.5-ohm Style D.N.-22B.H. track relay, you can set R_x at about 1 ohm per cell above the break point. R_t should then be set to provide working current at minimum ballast. R_t will be about 3 ohms per cell. In long track circuits there is not much advantage in using more than two or three cells in series, but in shorter track circuits a much higher voltage can be used.

Cicero Yard on the C.B. & Q. Shorter track circuits in advance of switches are now feasible.

Alternating current or A.C.-D.C. track circuits have better shunting performance at the same corresponding voltages, because the film current-resistance characteristic tends to knock off the peak of the A.C. wave.

In general, we have found that raising

the battery voltage to about three or four volts, with about four amperes short circuit current, has resulted in satisfactory shunting on branch lines, when a slow pick-up track repeater relay is used to cover momentary losses of shunt. Of course, excessive sanding creates an unshuntable condition, and should be prohibited.

Where rail or wheel film has created a shunting problem on main or branch lines, we recommend the use of two lead or three nickel storage cells in series or equivalent, a 0.5-ohm Style D.N.-22B.H. relay with series resistor, and a slow pick-up Style D.N.-18 track repeater relay or plug-in equivalents. For short detector track circuits, as in automatic classification yards, we recommend the Style F.R. Hi-Shunt track circuit.

More about the decoding transformer.

At the request of the editors, Mr. Staples has expanded his discussion of the decoding transformer.

The rectangular hysteresis loop material performs the same function as the magnetic stick code following relay in the other arrangement, i.e., the winding energy has to be pole changed at the code frequency in order to actuate the decoding equipment. Thus, any difficulty in the circuit, or improper phase, renders the circuit inoperative.

If ordinary transformer steel were used, one of the input windings could be coded with the other input winding open; and an output voltage would be obtained, because the flux would drop to a relatively low value during the « off » period of energization. While the output would be less than half of the nominal output when pole changed, it might be sufficient in certain cases to hold up the decoding relay. However, with the rectangular hysteresis material, the flux remains at the same level when energy is cut off, so that if it is not pole changed, the steel saturates in a short period and no further output is obtained until a reverse magnetizing force is applied.

Obtaining a square wave alternating voltage output is primarily a matter of design of the transformer. The output voltage is the induced voltage in the secondary, less the I.R. drop. The primary induced voltage is essentially the impressed voltage, less the primary I.R. drop. The primary current is made up essentially of the load current and the magnetizing current; but, of course, the magnetizing current is related to the induced voltage.

As long as the transformer does not saturate, the magnetizing current is relatively small and the I.R. drops are also relatively small, so that the output voltage is approximately a square wave, when the input voltage is a square wave. The higher the permeability, the lower will be the magnetizing current and the closer the output will be to a square wave. It is necessary to use a big enough core structure that it will not saturate during half of the code cycle.

Since the induced voltage is a function of the rate of change of flux, the total flux change in the structure is a function of time, so that the bigger the structure, the longer it will take to saturate. A core size was selected which would not change from saturation in one direction to saturation in the opposite direction, during a half code cycle. At the minimum energization of the equipment, this establishes the minimum rectified D.C. energization which has to be applied to the primary windings; at this point the load current is sufficient to energize the decoding relay. As the energy is increased beyond this point, as under high-ballast conditions, the impressed and induced voltage will be greater and the transformer may saturate in less than a half cycle. This could result in a peaked output voltage, if carried to an extreme. However, the output energy during the half cycle remains substantially the same, because the voltage and current output are increased but last for a shorter time. Since the relay itself is an integrating device, it operates with approximately the same margins regardless of the energization of the decoding transformer above the minimum working conditions.

[625 .162 (43)]

Crossing barrier installation.

(*The Railway Gazette*, December 11. 1959.)

There are still some 18 000 level crossings over main lines in Western Germany. Many have flashing light warning signals but at others lifting barriers are provided, controlled in various ways. In some cases their satisfactory operation offers special problems. An example of this is seen at Ingolstadt, where a new installation of power operated barriers with push-button control recently has been provided to cover the point where a newly widened roadway traverses the single-line railway connecting Ingolstadt with Donauwörth. The eight barriers are of special light-weight construction in aluminium alloy; four are about 33 ft. long and cover the highway, while the remainder are somewhat shorter and fall across the cycleways and pavements. Counterweights have been expressly avoided for clearance and aesthetic reasons and the barriers are equalised by special spring mechanisms. The installation, which was furnisled by Siemens & Halske A.G., from their Braunschweig works, presents a very neat appearance, the barriers being hardly noticeable in the normal position. The gateman controls the working to the best advantage, guided by electric announcement of the approach of trains, so as to cause the least possible delay to road users.

Electrically-operated crossing barriers at Ingolstadt, showing separate booms covering cycleways and pavements.

Control panel and diagram for working crossing barriers.

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

ENLARGED MEETING OF THE PERMANENT COMMISSION
(BRUSSELS, 1960).

[656 .25]

QUESTION 1.

The effect of electric traction on signalling and communication circuits, in particular reference to the means of overcoming interference, to provide safety and good communications.

ADDENDUM AND CORRIGENDA TO REPORT, (*)

by Sven Svensson,

Elektrotekniska Byrån, Kungl. Järnvägsstyrelsen, Sweden.

and J.A. Broughall,

Electrical Engineer (Development), British Transport Commission, British Railways Division.

After the publication of our Report, we received a demand from the Japanese National Railways to make the following alterations and additions relative to the information they supplied in answer to the questionnaire.

I. — CORRIGENDA.

Table 1. — *(Pages 338/2 and 339/3).*

	There is		*It must be*	
1.3	D.C. 1 500 V	A.C. 50 + 60 c/s 20 kV	D.C. 1 500 V	A.C. 50 + 60 c/s 20 kV
1.31	991	77	1 053	162
1.32	1 217	18	1 262	18
1.33	4 592	142	4 769	254

Note. — Electrification has been extended during period July 1959 - June 1960.

(*) See " Congress Bulletin " for April 1960, p. 337.

Table 2b. — *(Page 346/10).*

	There is	*It must be*
1.22	Transformers fed from 3-phase public network. Scott transformers **will** be used.	Transformers fed from 3-phase public network. Scott transformers **are** used.

Note. — Scott connection is adopted since March 1960.

Table 3a. — *(Page 348/12).*

		There is	*It must be*
1.473		—	Similar to initial rate of rise of current.
1.412	*contact wire*	—	85 to 170
	catenary	—	90 to 135 steel

Table 3b. — *(Pages 350/14 and 351/15).*

<table>
<tr><th colspan="3"></th><th>There is</th><th colspan="2">It must be</th></tr>
<tr><td>1.46</td><td colspan="2">Load current normal</td><td>400</td><td colspan="2">Signalling : 400 (*).
Telecomm. : Evaluated from time table.</td></tr>
<tr><td>1.471</td><td colspan="2">Short circuit current</td><td>1 500</td><td colspan="2">Signalling : 1 500 (*).
Telecomm. : Evaluated from impedances of source, transformer and line.</td></tr>
<tr><td rowspan="2">1.412</td><td colspan="2">Contact wire</td><td>85 to 170</td><td colspan="2">Standard : 85 to 110 (**).</td></tr>
<tr><td colspan="2">Catenary</td><td>55 steel</td><td colspan="2">Hitherto : 55 steel.
Recently : 60 Cd-Copper.</td></tr>
<tr><td rowspan="4">1.444</td><td rowspan="2">Normal</td><td>Mean</td><td>45</td><td>40</td><td rowspan="4">(***)</td></tr>
<tr><td>Max.</td><td>—</td><td>48</td></tr>
<tr><td rowspan="2">Emergency</td><td>Mean</td><td>45</td><td>77</td></tr>
<tr><td>Max.</td><td>—</td><td>89</td></tr>
</table>

Notes.

(*) In calculating interference to signalling circuit, the normal current which will not cause faulty action of track relay due to unbalance current between rails of a track is assumed at 400 A allowing some margin; and the fault current which shall not cause hindrance other than faulty action, e.g. damage to signal device, is assumed at 1 500 A.

On the other hand, when calculating interference to telecommunication circuits, the current value used to check whether values of longitudinal induced voltage and psophometric voltage in the case of normal operation are within the limits, is evaluated from time tables, while in the case of fault condition, the value of fault current used to check whether value of longitudinal induced voltage is within the limits is calculated from impedances of power source, transformer and line.

Therefore, the current values used in calculating interference to signalling circuit and telecommunication circuit are not always the same.

(**) Various sizes were tested including 170 mm², and it is decided to use 85 sq. mm as standard.

(***) Several new substations are in operation with extention of electrification, and these figures are obtained.

Table 5. — *(Page 356/20).*

		There is	*It must be*
1.511	*Between rails of one track*	—	Approx. 500 except where track circuits are used.
	Between tracks	—	D.C. : Interval, at least with one block section in between. A.C. : None.
1.514	*Earthing arrangements*	See text.	D.C. : Steel masts earthed (*). A.C. : Connected to return conductor solidly or via spark gap.
1.518	*Normal working condition*	A.C. : 20 to 100. D.C. : 160 to 500.	A.C. : 20 to 100 (**). D.C. : 40 to 120.
1.519		Approx. 0.6 $\angle$ 75° at 50 c/s 7.0 at 800 c/s	Single track : Approx. 0.6 $\angle$ 75° at 50 c/s 7.0 at 800 c/s Double track : Approx. 0.5 $\angle$ 75° at 50 c/s

Notes.

(*) Description regarding Item *1.514 (Earthing arrangements)* is not stated in text.

(**) Evidently value " D.C. 160 to 500 V " of column " *There is* " was obtained by assuming $I_c = 2\,000$ A for formula V max. = $(0.08 \sim 0.25)\, I_c$ which gives the maximum rail voltage of single track.

However, the maximum value of I_c in the case of J.N.R. single track is actually about 300 A, and therefore the D.C. voltage of rail is $24 \sim 75$ V.

Moreover, inasmuch as the leakage resistance of double track for maximum current 2 000 A in the case of double track line is $0.25 \sim 2.5\ \Omega$/km and since parallel feeding is performed, V max. is as follows :

$$\text{V max.} = (0.02 \sim 0.06)\, I_c$$

$$\text{substituting } I_c = 2\,000$$

$$\text{thus, V max.} = 40 \sim 120 \text{ V.}$$

Table 7. — *(Page 368/32).*

	There is		*It must be*	
	D.C.	A.C.	D.C.	A.C.
2.211	Min. 4 Mean 7 (if no filters are provided, 5 times these values).	—	Min. 4 Mean 7 (if no filters are provided, 5 times mean value).	—
2.212.4	Standard transposition scheme : number of transpositions per mile not given.		Minimum distance between transpositions : 200 ~ 500 m, thus, 32 transpositions per 6.4 ~ 16 km.	

Table 8. — *(Page 370/34).*

		There is		*It must be*	
		D.C.	A.C.	D.C.	A.C.
2.221		Signalling cables .... Telecom. cables old installation : overhead in trough, ...	....	Signalling cables .... Telecom. cables old installation : overhead **or** in trough, ...	....
2.223	*Distance from nearest rail in metres*	—	Sign. approx. 1.5 Telecom. : 3 to 5	Sign. approx. 1.5 Telecom. : 3 to 5	
	Height over rail in metres	—	Signall. buried 0.6 below ground level : troughs on ground. Tele.: 1 m below ground.	Signall. buried 0.6 below ground level : troughs on ground. Tele.: 1 m below ground.	
2.224.1	*Sheath*	Signalling : Vinyl. Telecommunication : New : as A.C. Old : lead.	Polythen or vinyl.	Signalling : Vinyl. Telecommunication : New : as A.C. Old : lead.	Polythen or vinyl + copper tape and steel tape.

Note. — In regards to the statement given in the paragraph starting on 10th line from the bottom of left column of p. 38, the plastic cables used in A.C. section of J.N.R. are in all cases provided with copper and steel layers. In local lines, aluminum tape is used instead of copper and steel.

Table 10a. — *(Page 380/44).*

	There is	*It must be*
3.311.44	Track relays A.C. rectifier or two elements induction type.	Two elements induction type, rarely A.C. rectifier type.

Table 10b. — *(Pages 384/48 and 385/49).*

	There is	*It must be*
3.312.2	Protector, series reactor and resister at both ends.	Protector, series reactor, resistor and arrester at both ends.
3.312.4	—	All harmonics considered.
3.312.51	Even harmonics, e.g. twelfth and sixteenth for two position track circuits; odd harmonics, e.g. fifteenth and nineteenth, for three position track circuits.	Even harmonics, e.g. (*) twelfth and sixteenth for 60 c/s traction; odd harmonics, e.g. fifteenth and nineteenth, for 50 c/s traction.

Note. — (*) Revision is made because three position system has been recently adopted in 60 c/s traction section where previously only two position system was used.

Table 12. — *(Page 390/54).*

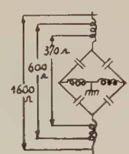
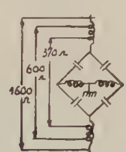
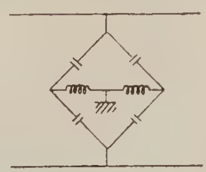
	There is	*It must be*
3.331.1		(Addendum) If necessary, filtered drainage coil used. 
3.331.2	Filtered drainage coil used. 	Filtered drainage coil used. 

Table [Item *2.11*]. — *(Page 366/30).*

	There is	*It must be*
	Normal operation 50 c/s 100 000	Normal operation 50 c/s 100 000
(2) Return conductor current amps	386 ∠ 186° 3′	386 ∠ 180° 3′

Page	*Column*	*Line*	*There is*	*It must be*
364/28	right	5	180 million yen per kilometer	1.8 million yen per (*) kilometer
374/38	right	8 (from bottom)	every 15 km	every 5 km (**)

Note. — (*) - (**) Misprint in J.N.R. Answers.

II. — SUPPLEMENTS.

1) The following is supplemented to Item 1.516 of J.N.R. Answer :

The impedance of double track for 50 c/s is 0.40 ∼ 0.56 ∠ 78° Ω/km. This value varies according to the current flowing in the rails, the type of rail used, track gauge and earth conductivity, etc.

Table A gives an example.

Table A. — Impedance of double track (Ω/km).
Rail: 50 kg. — Gauge: 1.067 m. — Distance between track centers: 360 cm.

c/s	*Rail current*	*Earth resistivity* 1 000 Ω.cm		*Earth resistivity* 10 000 Ω.cm		*Earth resistivity* 100 000 Ω.cm	
50 c/s	100 A	0.394	∠ 78° 03′	0.467	∠ 79° 54′	0.536	∠ 81° 15′
	200	0.404	∠ 77° 19′	0.475	∠ 79° 13′	0.545	∠ 80° 37′
	300	0.412	∠ 75° 22′	0.483	∠ 77° 33′	0.552	∠ 79° 11′
	500	0.420	∠ 73° 28′	0.488	∠ 75° 56′	0.560	∠ 77° 42′
60 c/s	100 A	0.469	∠ 78° 18′	0.553	∠ 80° 01′	0.640	∠ 81° 23′
	200	0.478	∠ 77° 10′	0.563	∠ 79° 08′	0.650	∠ 80° 34′
	300	0.486	∠ 75° 54′	0.571	∠ 78° 01′	0.657	∠ 79° 33′
	500	0.497	∠ 74° 06′	0.580	∠ 76° 28′	0.666	∠ 78° 13′

2) The following is supplemented to Item 1.519 of J.N.R. Answer :

The impedance of a double track line feeding circuit varies according to the amount of current flowing in the two contact wires. An example of calculation results for 60 c/s system is given in Table B. As shown in the Table, if there is no current flowing in either one of the two contact wires, the impedance of the double track feeding circuit using cadmium copper catenary would be about 0.49 $\angle$ 75° Ω/km.

Table B. — Double track feeding circuit impedance.

Contact wire		110 Cu		110 Cu	
Catenary		Steel		60 Cd Cu	
Rail		50 kg		50 kg	
Contact wire current (A)		*Contact wire / rail impedance of track 1*			
Track 1	*Track 2*				
100	0	0.662	$\angle$ 74° 58′	0.490	$\angle$ 75° 16′
100	50	0.730	$\angle$ 75° 27′	0.560	$\angle$ 75° 52′
100	100	0.803	$\angle$ 75° 54′	0.629	$\angle$ 76° 24′
100	200	0.941	$\angle$ 76° 35′	0.769	$\angle$ 77° 10′

3) Regarding Table (Equivalent disturbing current) on page 363/27 of Report :

Although the higher harmonics, given in Item 1.522.2 are the values of measurement by tests, they are larger than actual values. It is because a small capacity power source was used for the tests and therefore the measured values also contained the harmonics caused by the distortion of the source. Particularly in the measurement of 64 kVA booster transformers, this influence caused by the distortion of test power source is remarkably large when no load current exceeds 20 A.

Thus the equivalent disturbing currents shown in page 363/27 of the Report are considerably larger than actual values.

4) Regarding Table 8, Items 2.224.3 and 2.224.4 :

The test voltage of paper cables for telecommunication is 350 V and the specification of recent plastic cables also provides for the same voltage for the time being. However, actual measurements show that the core to sheath and core to core breakdown voltages of such plastic cables are above 2 000 V and 1 500 V respectively.

5) Regarding J.N.R. Answer to Item 3.312.4 :

Summary of references, Railway Technical Research No. 6 and No. 7 is as follows :

It is desirable to block the higher harmonics of the interfering voltage above and below signal frequency by means of a band pass filter with steep attenuation characteristics. Generally they are odd harmonics.

When one of higher harmonics of interfering voltage passes through the filter, it will be a continuous wave with the frequency approximating that of the signal. If two of higher harmonics simultaneously pass through, their wave form will be a beat pattern.

When the signal is transmitted in continuous wave under this circumstance, no discrimination can be made between the interfering voltage and the signal voltage.

For this reason, the signal wave is amplitude-modulated by a certain low frequency, which is preferably as far below that of the traction current as possible. Under this arrangement, the signal voltage can be easily picked out for amplification by the selective amplifier of low frequency after detection. Finally it is rectified to excite D.C. relay.

This procedure can successfully prevent the faulty action of relay due to interfering voltage. In case one arm of impedance bond is broken, allowing 100 % unbalance current to flow, the faulty action of relay can still be prevented by inserting a voltage limiter after the detector.

The interval between the two adjacent odd harmonics of interfering voltage in 50 c/s A.C. electrified territory is narrower by 20 c/s than that in 60 c/s A.C. electrified territory.

It is possible to make the signal frequency match the even harmonics and block odd ones in 60 c/s A.C. electrified territory.

On the contrary, in 50 c/s A.C. electrified territory, two odd harmonics are liable to come into the pass band of the filter in such case. It is more desirable, therefore, to make the signal frequency match the odd harmonics, though the latter comes into the pass band.

Thus all harmonics are considered.

For further details, please see references Railway Technical Research No. 6 and No. 7.

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